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The impacts of the Lacey Act Amendment of 2008 on U.S. hardwood lumber and hardwood plywood imports

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ABSTRACT

The Lacey Act of 1900 was amended on May 22, 2008, to prohibit the import of illegally sourced plant materials and products manufactured from them into the United States and its territories, and to similarly ban their interstate transport. Trade theory suggests that the effect of the new law would be to reduce the flow of illegally sourced fiber into the United States, increasing prices. Monthly U.S. import data on tropical lumber (January 1989–June 2013) and hardwood plywood (January 1996–June 2013) quantity and unit value were used to estimate alternative statistical models that quantify the impact of the 2008 Lacey Act Amendment on import prices and import quantities of products from potential source countries. Results show that the Amendment's quantity effects are generally negative and double in magnitude in percentage terms than the price effects, consistent with expectations of the effects of a backwards shift in foreign supply against an elastic import demand. Models indicate that there have been double-digit percentage increases in prices and decreases in quantities of tropical lumber imports from Bolivia, Brazil, Indonesia, Malaysia, and Peru. Similarly large changes in hardwood plywood import prices and quantities from Brazil, Indonesia, and Malaysia have occurred, while smaller, and in some cases statistically insignificant, changes have been observed for hardwood plywood imports from China, Ecuador, and Taiwan.

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1. Introduction

The Lacey Act is a U.S. wildlife protection and anti-trafficking statute that makes it a crime to import onto U.S. territory or to transport across any state line within the U.S. or its territories any plant or animal species or derivative product made with such plants or animals that were obtained illegally. The original Lacey Act of 1900 was focused especially on the trafficking of illegally acquired wildlife, while later amendments expanded its concern to include plants. The Lacey Act Amendment of May 22, 2008[1] includes for the first time any tree species illegally obtained in the country of origin. Any product containing illegally obtained tree material (e.g., wood, paper, pulp) is now banned for import and interstate trade. Importers must also, as of December 15, 2008, file Plant and Plant Product Declaration form 505 that lists any and all tree species being imported. Although the date when this form was required upon importation varied from product to product, the Amendment stipulates that importers must adhere to the requirements regarding legal sourcing immediately.

The Lacey Act Amendment of 2008 (LAA) was enacted most proximately as a way of reducing aggregate demand for illegally obtained timber products globally. Although the United States consumes a relatively small share of wood exported by countries suspected of having high rates of illegal logging (Seneca Creek Associates, 2004; Li et al., 2008), having such material entering global markets serves to depress world wood product prices, indirectly and negatively affecting U.S. producers. Moreover, with the LAA's "due care" requirement, the U.S. has sought to set an example of what importing countries could do to help discourage illegal logging, with the hope of leading others to carry out similar policies and programs. Indeed, in 2010, the European Union enacted EU Regulation No 995/2010 (EU Timber Regulation or EUTR), which similarly bans the import of illegally sourced fiber and requires importers of such products into EU member countries to carry out "due diligence" in the tracking of imported timber products.

Measures such as the LAA and EUTR are part of a larger set of policies and programs designed to discourage illegal fiber production worldwide. The U.S., for example, operates bilateral technical assistance programs that work with the forest sector in many suspected source countries. Sometimes these efforts are coupled with free trade arrangements—for example, the U.S. Peru Trade Promotion Agreement of 2006 (Office of the United States Trade Representative, 2007). The European Union has similarly targeted programs of institution building, including the centerpiece Forest Law Enforcement, Governance and Trade (FLEGT) program. Several other countries also work actively on a bilateral basis to address illegal fiber sourcing through trade measures and institution building, as well. The Asia-Pacific Economic Cooperation economic forum established in 2011 an Expert Group on Illegal Logging and Associated Trade to seek out potential solutions.

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[1] The Lacey Act was amended in the Food, Conservation, and Energy Act of 2008 (P.L. 110–234, 122 Stat. 923).

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For the U.S., the EU, and other countries enacting or considering similar trade measures focused on imports, a key question is whether laws such as the LAA will effectively reduce imports of illegally sourced wood. There is no way to directly measure the flow of illegal fiber into the U.S. or any other country, because governmental officials are so far unable to physically detect an illegal product using available tools. Policy makers and those interested in the question of illegal fiber sourcing instead use indirect ways of identifying the effects of trade measures or other forms of intervention. For example, Lawson and McFaul (2010) sought to obtain evidence on the effects of the LAA and FLEGT and other bilateral and multilateral efforts by surveying government officials, non-governmental organizations, and firms, in addition to evaluating recent trade and production data from destination and potential source countries. They found that, since the early- to mid-2000s, exports of illegally sourced wood fiber had declined, timber product prices had risen, rates of illegal logging had dropped, and certification of forestry operations in the countries that they analyzed had significantly expanded.

Since the Lawson and McFaul (2010) study was carried out, however, additional international trade data have accumulated that might bolster the evidence on the effects of the LAA as a trade measure: has it affected prices and quantities of imports into the U.S. of products deriving from countries suspected of having substantial illegal production (or whose exports may contain illegal content)? Aside from its indirect link to on-the-ground activities in suspected source countries, one challenge facing analysts of trade and production data is that the implementation of the LAA nearly coincided with a weakened building sector in the U.S. (although housing starts in the U.S. had increased by about 70% by June of 2013 from their 2009 lows (U.S. Department of Commerce, Bureau of the Census, 2014)) and with the global recession of 2007–2009 (although the U.S. economy was larger by 4% in real terms by mid-2013 than its pre-recession peak in late 2007 (U.S. Department of Commerce, Bureau of the Economic Analysis, 2014)). However, this near-coincidence is not an insurmountable barrier to the detection of the trade effects of the LAA. Methods are available that can strip away such influences, attempt to isolate other factors, and allow for the law's detection in the trade data. Given long enough time series following the LAA enactment (e.g., to 2013) and appropriate statistical models, even the effects of these potentially confounding factors can be largely controlled for.

The objective of this study is to detect the effects of the LAA on the quantities and prices of products imported into the U.S. from suspected source countries. To do this, we estimate two classes of statistical intervention models. These include simple single variable models—i.e., univariate or multivariate autoregressive models of individual time series of prices and quantities. These models quantify the effect of the LAA by measuring how the autoregressive structure of price[2] and quantity time series may have shifted at the same time that the LAA was implemented. Somewhat more complex are those involving the estimation of cointegrating relations of two or more variables. These models identify the effect of the LAA by quantifying any shift in these cointegrating relations that corresponds with the implementation of the LAA. Another, even more complex, class of intervention models could also be estimated—one based on the full structural relation of supply and demand. However, the data demands of such models are great, requiring data often not available in the same frequency as the most frequently reported import data or not available for particular variables needed for full specification.

One contribution of this research is to document that both intervention modeling approaches used in this study can be used to quantify the effect of the LAA and that the effects that they quantify are similar for those cases where they can be employed and compared. Another contribution is that we quantify the impacts of the LAA on U.S. imports of these products from a variety of countries suspected of providing illegal fiber to world markets, including to the U.S. This impact assessment provides a benchmark for policy makers interested in understanding the effects of this new trade measure, perhaps informing expectations about the effects of similarly proposed measures that could be enacted by other countries on their imports.

[2] In this study, we employ the term "price" interchangeably with the term "unit value," as trade data are originally reported in total quantities and total values; unit value is the ratio of total value to total quantity for the products analyzed.

2. Methods

2.1. Univariate intervention models

Intervention analytical methods are common tools in assessing the magnitude and, with time series data, the temporal dynamics of shocks to data generating processes. In the forestry sector, intervention analysis (Enders, 1995) has been employed to quantify the effects of policies (e.g., Prestemon, 2009) and biophysical shocks (Holmes, 1991; Prestemon and Holmes, 2000, 2004). Consider a univariate stationary time series data generation process of an economic variable, P_t, which evolves as:

$$\begin{aligned} P_t &= \alpha_0 + \sum_{j=1}^{J} \alpha_{1,j} P_{t-j} + \eta_t \\ \eta_t &= \lambda S_t + \varepsilon_t \end{aligned}, \tag{1}$$

where t indexes time; α_0 is a constant; J is the order of autoregression of the stationary process; ε_t is a zero-centered random error process; η_t is a "noise" process containing a shock (S_t); and λ, the parameter of particular interest, quantifies the effect of the shock on the data generation process. With time series information on the level of P_t and on the timing and magnitude of S_t throughout periods $t = 1,\ldots, T$, a statistical model can be estimated that quantifies the parameters in Eq. (1). The shock in statistical models is often specified as a dummy variable, equal to zero before it occurs and 1 at the time of its occurrence (but it does not need to be so restricted). To powerfully identify the parameters of Eq. (1), a "long" time series is needed that has sufficient observations before and after the shock occurs. The larger the variance of ε_t, and σ_ε^2, the longer time series of P_t needed to identify λ.

Often, P_t is nonstationary, such that $\alpha_{1,1} \geq 1$ or $\alpha_{1,1} \leq -1$. In that case, Eq. (1) is not estimable. Alternatives include modeling a shock by differencing the economic variable or modeling it in a multivariate context. Prestemon (2009) showed that modeling a shock with a first-differenced non-stationary variable is a statistically weak approach. A more powerful intervention modeling approach for a nonstationary process involves cointegration.

2.2. Cointegration intervention models

Prestemon (2009) showed that, if a nonstationary P_t is involved in a cointegrating relation with another nonstationary variable R_t but the shock S_t is contained in the "noise" process of P_t but not that of R_t, then the parameter λ can be identified with greater power by modeling how the relation between P_t and R_t changes due to the shock. The two variables may contain a cointegrating relation through either a direct arbitrage process or through a shared relationship to a third variable (e.g., a substitute or a complement) in a production process that demands them both. Describe the bivariate relation, including the shock, as:

$$\begin{aligned} P_t &= \gamma_0 + \gamma_1 R_t + \theta_t \\ \theta_t &= \mu_t + \lambda S_t \end{aligned}. \tag{2A}$$

In this case, as long as the innovations, μ_t, are distributed as in Dickey and Fuller (1979) and Said and Dickey (1984), then Eq. (2A) can be estimated as recommended by Engle and Granger (1987), as a cointegrating relation with a shock variable, S_t.

Prestemon and Holmes (2000) used a cointegration intervention model involving a differences-in-differences approach to measure the effect of a shock—in that case, the 1988 Hurricane Hugo—on prices of timber in South Carolina. Their approach was to divide the time series of prices (P_t) spanning the shock ($t = 1,\ldots,T$) into two segments, the first covering the periods (in their case, quarters) before the shock, $t = 1$ to $t = T_1$, the second covering periods $t = T_1 + 1$ to T. Eq. (2A) was then estimated over the pre-shock segment, producing estimates, $\hat{\gamma}_0$ and $\hat{\gamma}_1$, of parameters γ_0 and γ_1, respectively. The authors then used these parameter estimates to generate predicted "pseudo-errors", $P_t - \hat{\gamma}_0 - \hat{\gamma}_1 R_t = \hat{\mu}_t$, in the cointegrating relation for both segments, i.e., $t = 1$ to $t = T$. These pseudo-errors contained the shock because the parameters of cointegration were estimated using data from the pre-shock segment and therefore did not model the shock. Using the Prestemon and Holmes (2000) approach, then, the pseudo-errors time series can be used to estimate using least square regression the size of the shock, λ, as:

$$\hat{\mu}_t = \omega_0 + \sum_{j=1}^{J} \omega_j \hat{\mu}_{t-j} + \lambda S_t + \varepsilon_t \tag{2B}$$

over $t = 1$ to T. In Eq. (2B), J is the order of autoregression in the cointegrating relation, ω_0 and ω_j's are parameters to be estimated, and λ and S_t are as previously defined. An assumption embodied in Eq. (2B) is the ε_t are white noise.

The approach outlined in Eqs. (2A) and (2B) might be particularly appropriate for cases where, say, one country has been suspected of exporting illegally sourced wood fiber to the United States (e.g., Brazil) while another (say, Canada) has not. Continuing with this example, if the time series of an economic variable (e.g., price or quantity) of a timber product imported from Brazil contains the effect of the shock (the LAA, in this case) and the time series of the analogous economic variable from Canada does not, and if the economic variables from both countries follow a common trend mediated through an output process that demands products from both source countries (e.g., construction or furniture making in the U.S.), then an estimate of (2A) and (2B) using data on quantities from both countries may yield a consistent estimate of the effect, λ.[3]

2.3. Empirical approach

In the empirical models estimated for this study, we estimate Eqs. (1), (2A) and (2B), for import prices and import quantities. In Eqs. (2A) and (2B), the import source country that we believe is not significantly affected by the LAA but which may contain significant cointegrating relations with the import prices or import quantities from other countries is Canada, the United States' primary source of most wood product imports. As well, we specify the shock variable, S_t, as a dummy variable in Eqs. (1), (2A) and (2B), and in all other equations estimated in this analysis, that is equal to 0 before the advent of the LAA and 1 thereafter. Research has shown (Buongiorno et al., 1988; Uusivuori and Buongiorno, 1990, 1991; Bolkesjø and Buongiorno, 2006) that permanent or transitory effects of exchange rates could influence how import prices and hence import quantities adjust to the LAA, particularly if exchange rates are changing significantly (as many did with respect to the U.S. dollar) over the time span being modeled. If P_t is the price of an imported timber product which is denominated in U.S. dollars, importers may respond either immediately or slowly to the change in the exchange rate; slow or incomplete responses ("passthrough") may occur because existing contract arrangements sometimes guarantee previously agreed delivered quantities at a specified price, denominated in only one currency. The problem is slightly more complicated if P_t and R_t are both from imported products involved in a cointegrating relation; in that case, both foreign currencies' exchange rates with the U.S. dollar may affect the relation described in Eqs. (2A)–(2B).

To accommodate the possibility of incomplete passthrough, we augment all equations by introducing an exchange rate, U_t. Adding the exchange rate, units of foreign currency per U.S. dollar, to Eq. (1), yields

$$P_t = \alpha_0 + \sum_{j=1}^{J} \alpha_{1,j} P_{t-j} + \alpha_2 U_t + \varepsilon_t + \lambda S_t. \tag{3}$$

So, in addition to estimating Eq. (1), Eq. (3) is estimated for stationary import prices and quantities from suspected illegal timber product source countries. Eq. (2A), applying to cointegrating relations, is augmented to include the exchange rate of the two comparison countries as follows (with m indexing the exchange rate from the comparison country whose price or quantity does not contain the LAA shock):

$$P_t = \gamma_0 + \gamma_1 R_t + \gamma_2 U_t + \gamma_3 U_{m,t} + \mu_t + \lambda S_t, \tag{4A}$$

where the pseudo-errors are defined as $P_t - \hat{\gamma}_0 - \hat{\gamma}_1 R_t - \hat{\gamma}_2 U_t - \hat{\gamma}_3 U_{m,t} = \hat{\mu}_t$. The equation corresponding with (2B) is augmented similarly:

$$\hat{\mu}_t = \omega_0 + \sum_{j=1}^{J} \omega_j \hat{\mu}_{t-j} + \epsilon_t + \lambda S_t. \tag{4B}$$

Therefore, along with estimating Eqs. (2A)–(2B) where possible, Eqs. (4A)–(4B) are also estimated in this study using pairs of non-stationary prices or quantities from a suspected source (prices or quantities expressed as $P_{k,t}$) and a non-source country that we have identified as Canada (prices or quantities expressed as R_t). Cointegration between the variables appearing in Eqs. (2A) and (4A) is confirmed by evaluating both the results of the Engle–Granger two-step approach (Engle and Granger, 1987) and the Johansen (1991) maximum likelihood and trace statistics. The reader should be cautioned that the reliability of the cointegration approach to modeling a regime switch depends on the existence of stable relationships between paired price or quantity variables from affected and unaffected importing countries. For example, if the LAA did more than simply shift the differences between the modeled variables—e.g., had effects on the parameters of the error process—then estimates of the shock parameter could be biased.

In all of the above discussion about the effects of the LAA, we refer to a country or a pair of countries. In principle, the average effect of the LAA on prices and quantities, as measured by the parameters λ, c_M, and c_P, could be measured for individual countries or groups of countries in aggregate. There are two main reasons why quantifying the effects of the LAA on imports is best done using individual countries, i.e., adopting the Armington (1969) assumption that products may be differentiated by country of origin. First, as Seneca Creek Associates (2004) documented, the suspected rates of illegal logging vary widely across countries. Hence, the pre-LAA quantity of illegal fiber in traded forest products would also be expected to vary widely across countries. The effect of the LAA therefore would be different across countries, with smaller impacts likely for countries with low pre-LAA traded product illegal fiber content and larger impacts likely for countries with high pre-LAA traded product illegal fiber content. Second, the U.S. import share of the timber products from these countries varies widely across countries. Countries with small shares would likely be more elastically affected by the LAA, thus

[3] Note that any extra paperwork costs associated with filing Plant Product Declaration Form 505 are fully contained in the measured effect, λ, of the LAA in the univariate models (Eq. 1). The effects of this paperwork are also contained in the cointegration type of approach (Eqs. 2A and 2B), but they could be positive or negative, depending on whether any extra transactions costs are higher or lower for products from the suspected source country than from the comparison country series. We contend that these added costs are of second-order importance relative to the remaining effects of the import measure—the backward shift in supply related to higher costs of obtaining and assuring legality of wood fiber sent to the United States.

manifesting larger quantity (but perhaps smaller price) impacts. Constraining the effect of the LAA to be identical across countries by estimating an aggregate country model of the effects of the LAA, would therefore yield a single, biased and inconsistent shock estimate, applicable to the imported product from no country in particular.

We note that models (1), (2A)–(2B), (3), and (4A)–(4B) could be estimated using price or quantity variables expressed in their untransformed state and in their natural logarithm-transformed state. It is widespread in the empirical economics literature to expect that prices (at least) are more likely to be normally distributed after log-transformation; normality is needed for valid hypothesis tests on least squares estimates of parameters. Further, whether a variable passes a test of stationarity and whether two or more variables are identified as cointegrated may depend on whether the variable undergoes log-transformation. In our study, we evaluate all price and quantity effects for both untransformed and log-transformed variables.

2.4. Expectations of the effect of the Lacey Act Amendment

A graphical description of how the LAA may have affected import prices and quantities of products from suspected source countries can clarify the expected sign of any estimates of the shock parameters, λ, c_M and c_P. Fig. 1 shows a simple import demand and foreign product supply function. Initially (say, before the LAA), supply was S_0 and import demand was D. Their intersection at point *a* established the equilibrium import price and quantity, P_0 and M_0, respectively. Before the LAA, supply consisted of both a legal supply and an illegal supply. As shown, we assume that these combine to form the total supply curve S_0. With the enactment of the LAA, we imagine the disappearance of the illegal supply, amounting to a backwards shift of total supply, to S_1. The equilibrium market solution at point *b* establishes a higher price P_1 and a lower quantity imported M_1. In other words, after the May 2008 implementation of the LAA, prices would be expected to settle at a higher level and quantities at a lower level, other variables held constant.

2.5. Data

Data on monthly import quantities and values, beginning in January of 1989 (lumber products) or January of 1996 (hardwood plywood) and continuing to June of 2013, were obtained from the U.S. International Trade Commission (2013). Data on exchange rates were obtained from the Federal Reserve Bank of St. Louis (2014) and FXTOP.com (2013). Import prices were expressed as unit values, in U.S. dollars per cubic meter, following approaches used by other authors (e.g., Uusivuori and Buongiorno 1991, Buongiorno and Uusivuori 1992, Prestemon and Buongiorno 1996, Turner and Buongiorno 2004). Volumes were expressed in cubic meters. In some cases, apparent data anomalies for single months were noticed, with import quantities nearly an order of magnitude greater with little change in total values (and hence unit values nearly an order of magnitude lower) than in any other month(s) in the historical time series. In these cases, we introduced a dummy variable to capture the anomaly.[4]

We evaluated the effects of the LAA on 10-digit lumber data for five specific species or species groups; one 6-digit lumber aggregate; and on hardwood plywood for which sufficient time series information existed—i.e., products and countries for which imports into the U.S. were non-zero for at least 100 consecutive months since the start of a consistent time series (as early as 1989 for hardwood lumber and from 1996 for hardwood plywood). Generally, this worked to limit the countries analyzed to those with the largest quantities of product imports into the U.S. Table 1 shows how such categories were assembled from historical monthly data from the U.S. International Trade Commission (2013) for the lumber species: mahogany (4407.21.0000) from Bolivia and Peru; balsa (4407.22.0006) from Ecuador; imbuia–baboen (4407.22.0091) from Brazil; keruing (4407.29.0116) from Indonesia and Malaysia; and teak (4407.29.0131) from Malaysia. They also included a six-digit category (4407.99-other) from Brazil, Malaysia, and Peru. In the lumber cointegration models involving Canada, imports were dominated by the ten-digit temperate species appearing in the 6-digit aggregate category (4407.99-temperate), used in estimating models (2A), (2B), (4A) and (4B). We caution the reader that this more aggregated category of 4407.99 from Brazil and perhaps Peru and Malaysia (the three countries for which this was possible given a requirement for consistently imported products) which excluded the listed temperate species for Canada still have the possibility of including temperate species and, especially for Brazil, eucalyptus, which might have been erroneously classified in this way in some cases but perhaps derives from plantations. The current U.S. HTS code system does not have a separate code for eucalyptus.

There are recognized weaknesses of evaluating the effects of policies or other kinds of market shocks on aggregates of commodities, and our analyses of the 6-digit aggregate of other hardwood lumber and the aggregate of hardwood plywood carry with them these weaknesses. The primary concern is aggregation bias, wherein individual product component shares may shift within an aggregate, accounting for some of the measured effects of the policy or shock. The LAA could indeed cause exporters to alter their mixes of product lines that they send to the United States, just as the LAA could cause exporters to alter their mixes of illegally and legally sourced fiber sent to the United States. Finally, we need to emphasize that we seek to identify the apparent effect of the LAA on 10-digit commodities and on aggregates. In other words, we cannot make inferences about the effects of the LAA on individual product categories within the aggregates.[5] Another concern, unevaluated in this study, is how changes in components of declared import values

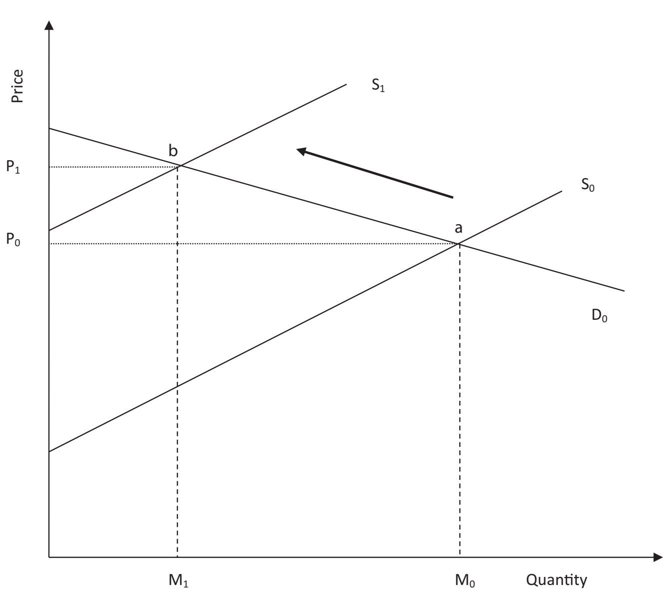


Fig. 1. Import supply and demand and the effect of the Lacey Act Amendment of 2008. Previous to the LAA, import demand (D_0) and supply (S_0) were at equilibrium point *a*, corresponding to import quantity M_0 and price P_0. Upon enactment of the LAA, supply shifted backwards, to S_1, reflecting a restricted legal supply compared to total, leaving a new equilibrium at point *b*, with a lower import quantity M_1 and a higher price P_1.

[4] Models that excluded these dummy variables had statistically worse fit but typically had similar measured effects price and quantity shifts compared to those that included them, and statistical significance of the measured effect was maintained.

[5] The 10-digit HTS code hardwood plywood categories in existence since July 2006 did shift their shares somewhat through 2013. For all six countries evaluated, five or fewer individual 10-digit HTS code products typically accounted for greater than 65% of the total quantity (and a single 10-digit commodity for greater than 90% of the hardwood plywood aggregate from Ecuador) from 2007 to 2013. Further, these dominant few categories and the remaining products outside these dominant few followed nearly an identical time series pattern (inter-annual percentage changes in quantity and unit values) over the 2007–2013 time span.

Table 1
Common names, Harmonized Tariff System (HTS) codes of products, and source countries of U.S. imports analyzed in this study.

Common name (species name)	HTS codes, 1989–1995	HTS codes, 1996–2006 (June)	HTS codes, 2006 (July)–2006 (December)	HTS codes, 2007–onward	Countries analyzed
Balsa (*Ochroma lagopus*)	4407.23.0005 4407.23.0010	4407.24.0005 4407.24.0010	4407.24.0006	4407.22.0006	Ecuador
Mahogany (*Swietenia* spp.)	4407.23.0025 4407.23.0030	4407.24.0025 4407.24.0030	4407.24.0026	4407.21.0000	Bolivia, Peru
Keruing (*Dipterocarpaceae*)	4407.21.0025 4407.21.0030	4407.29.0025 4407.29.0030	4407.29.0016	4407.29.0116	Indonesia, Malaysia
Teak (*Tectona grandis*)	4407.21.0005 4407.21.0010	4407.29.0005 4407.29.0010	4407.29.0031	4407.29.0131	Malaysia
Imbuia (*Ocotea porosa*) + Baboen (*Virola* spp.)	4407.23.0090 4407.23.0095	4407.24.0090 4407.24.0095	4407.24.0091	4407.22.0091	Brazil
Other hardwood lumber	4407.99	4407.99	4407.99	4407.99	Brazil, Malaysia, Peru, Canada
Hardwood plywood	Not assembled[a]	4412 (total plywood) *minus* 4412.19 (coniferous plywood)	4412 (total PLYWOOD) *minus* 4412.19 (coniferous plywood)	4412 (total plywood) *minus* 4412.39 (coniferous plywood)	Brazil, China, Ecuador, Indonesia, Malaysia, Taiwan, Canada

[a] Hardwood plywood in the 1989–1995 code system included many 6-digit categories that had both hardwood and softwood, so this portion of the time series was excluded from the datasets used in this study.

that are unrelated to the LAA, such as freight and insurance costs, may have changed over the span of the data we analyze in this study. Such costs could have trended in ways that would add to or subtract from the measured effects of the LAA using the methods applied in this study.

For models involving imports from several countries, we sought to statistically control for the effects of legal and policy changes that might have affected export supply. In all cases, the effects on domestic production in the target country would be expected to be negative, which should translate into a backwards shift in export supply. For U.S. imports of mahogany (4407.21.0000) from Bolivia and Peru, we included dummy variables for the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II, which listed mahogany in November of 2003 (a dummy variable equal to 0 through October 2003 and 1 thereafter), and CITES Appendix III, which listed mahogany in 1995 (a dummy variable equal to 0 through November of 1995 and 1 thereafter) (see Convention on the International Trade in Endangered Species of Wild Fauna and Flora, 2014). For imports of imbuia–baboen (4407.22.0091), other hardwood lumber (4407.99) and hardwood plywood from Brazil (4412), we included a dummy variable (equal to zero before 1996 and 1 thereafter) measuring a law passed in late 1995 (not immediately enforced) with a requirement that 80% of forest be retained upon clearing of private land; a dummy variable (equal to zero through December of 2000 and 1 thereafter) measuring when this law began to be enforced; and a dummy variable (equal to zero through December 2004, 1 thereafter) measuring the advent of upped law enforcement pressure against law violations, consistent with The Action Plan for Prevention and Control of Legal Amazon Deforestation (Evans, 2013). For U.S. imports of some categories of lumber and hardwood plywood from Indonesia, legal changes that we quantified included a dummy variable (equal to zero through December 2004, 1 thereafter) capturing Public Instruction 04 (PI-04) (Forest Legality Alliance, 2014); a dummy variable (equal to zero through June of 2009, 1 thereafter) which quantifies the effect of the Sistem Verifikasi Legalitas Kayu (SVLK) or Timber Legality Verification System, which upped efforts to ensure legal harvesting in that country; and a dummy (equal to zero through May of 2011, 1 thereafter), quantifying the effect of a government moratorium on all new natural forest concessions (Moratorium on Natural Forests and Peatlands in Conservation, Protection and Production Forests), which was extended through June of 2013 (the end of our dataset), according to the United Nations Office for REDD+ Coordination in Indonesia (2014). While the statistical effects of these variables on the prices and quantities of these products are not shown in the result tables, we report their effects in the Results section.

To address concerns that some economy-wide or macroeconomic factors also might be connected to price and quantity changes corresponding in timing with the LAA, we also estimate versions of Eq. (3) that include changes in U.S. housing starts (U.S. Department of Commerce, Bureau of the Census, 2014), real U.S. GDP (U.S. Department of Commerce, Bureau of Economic Analysis, 2014), and a measure of China real GDP (National Bureau of Statistics of China, 2014a,b,c). Such additions should help to reduce model uncertainty and the chance that estimated effects of the LAA are not confounded by other important factors affecting U.S. import demand and foreign country export supply.

Average import quantities from January 2000 through April 2008, just before LAA implementation, were as follows: mahogany (4407.21.0000) from Bolivia were 612 m^3/month and from Peru 2262 m^3/month; balsa (4407.22.0006) from Ecuador, 3450 m^3/month; imbuia–baboen (4407.22.0091) from Brazil, 1886 m^3/month; keruing (4407.29.0116) from Indonesia, 750 m^3/month, from Malaysia, 1569 m^3/month; teak (4407.29.0131) from Malaysia, 417 m^3/month; "other" hardwood species contained in 4407.99 from Brazil, 5529 m^3/month, from Malaysia, 277 m^3/month, and from Peru, 458 m^3/month. Monthly imports of temperate hardwood lumber species (4407.99-temperate) from Canada averaged 73342 m^3/month over this

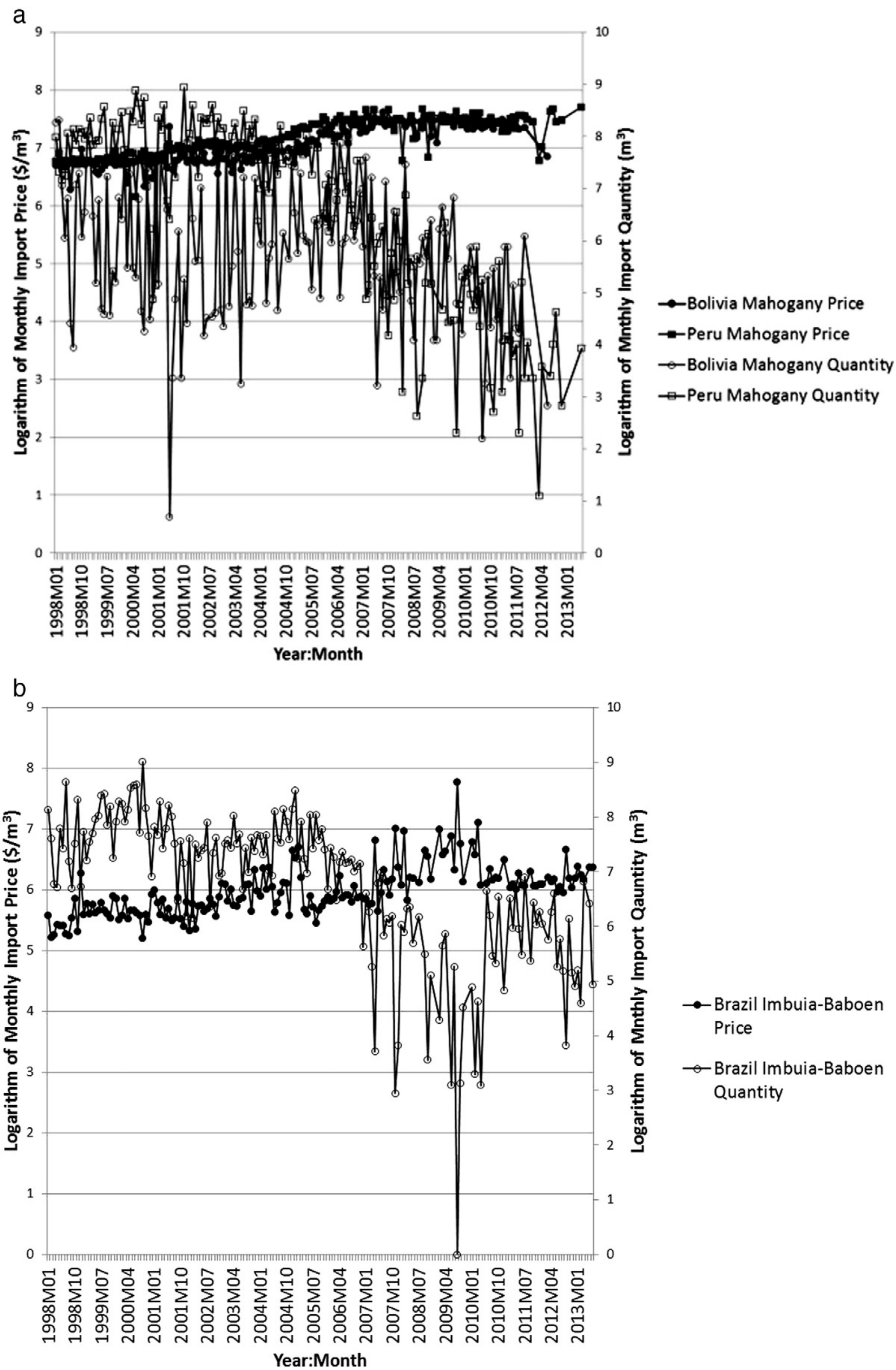
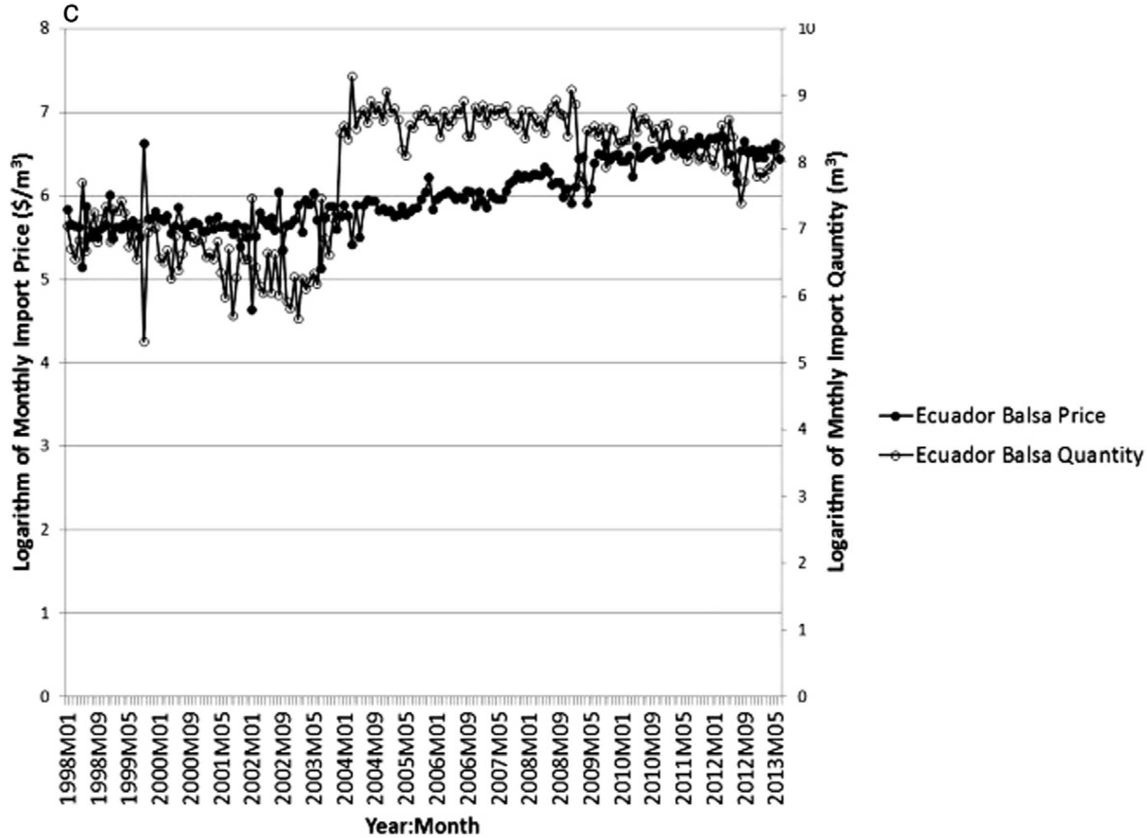


Fig. 2. Natural logarithm-transformed U.S. monthly import quantity (cubic meters) and unit value (US$/cubic meter) of (a) mahogany (4407.21.0000) from Bolivia and Peru, (b) imbuia and baboen (4407.22.0091) from Brazil, (c) balsa (4407.22.0006) from Ecuador, (d) keruing (4407.29.0116) from Indonesia and Malaysia, (e) teak (4407.29.0131) from Malaysia.



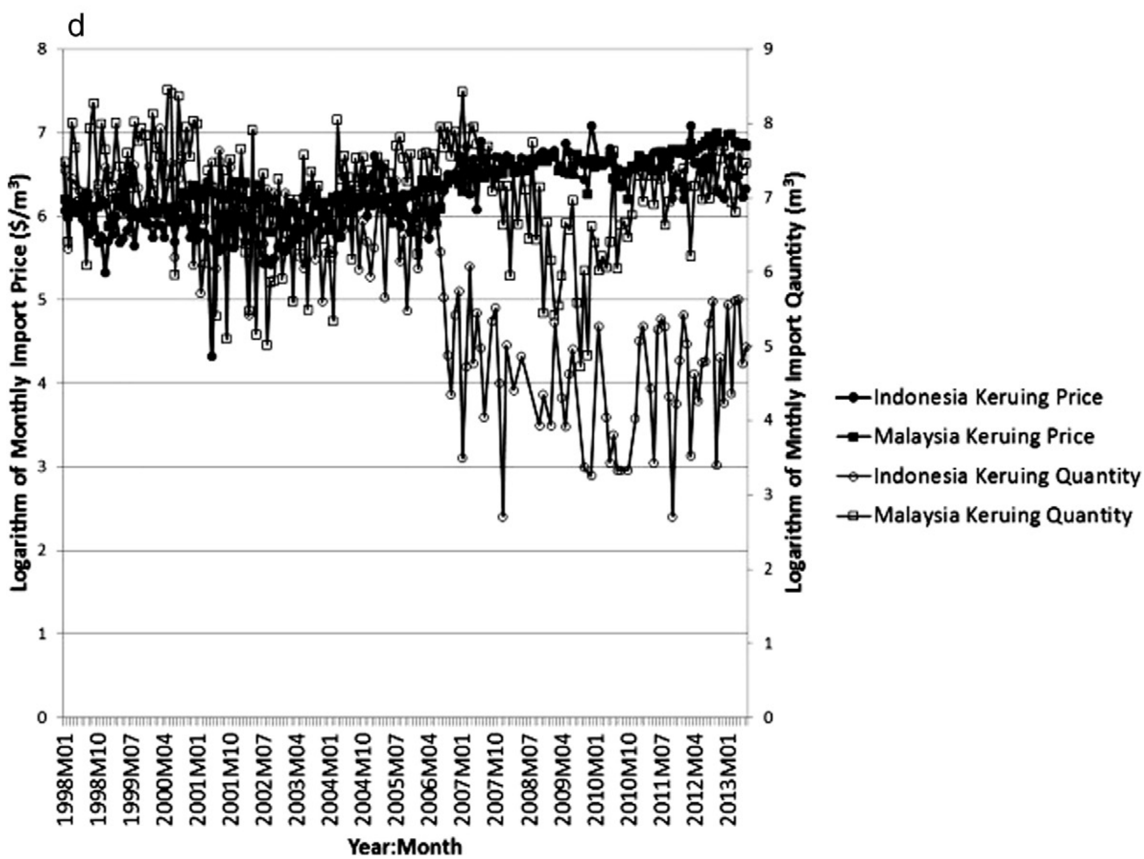


Fig. 2 (*continued*).

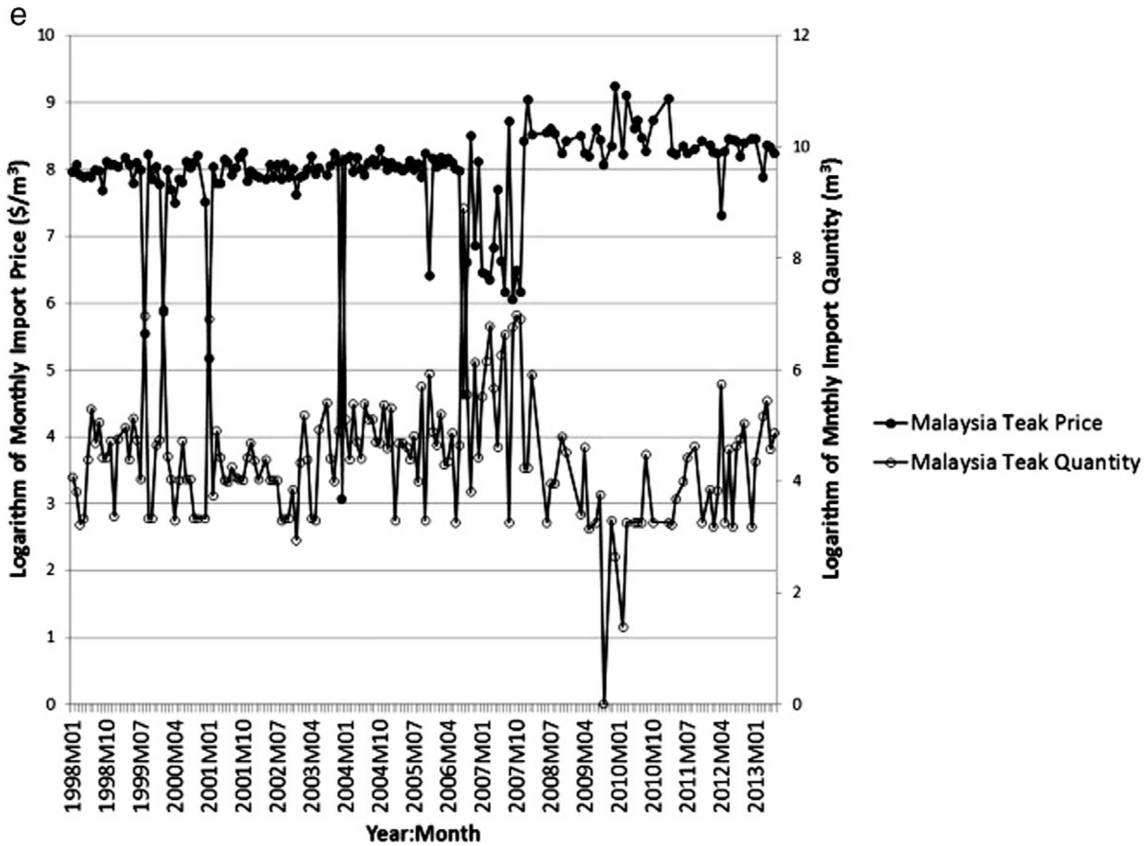


Fig. 2 (*continued*).

same time span. Time series of quantities and prices of these lumber imports are shown in Fig. 2a–e for the 10-digit products and Fig. 3a and b for the 6-digit aggregate lumber product (including Canada).

Hardwood plywood data could only be assembled from January 1996 onward, due to HTS code redefinitions. This meant subtracting coniferous plywood (HTS code 4412.19) from total plywood (HTS code 4412) for all months of the years 1996 through 2006 and subtracting coniferous plywood (HTS code 4412.39) from total plywood (HTS code 4412) for all months from January 2007 onward. We caution that this aggregate contains a diverse set of specific products (e.g., door skins, architectural panels, and laminated flooring of differing thicknesses), which might have been assembled at the 10-digit HTS code level but could not be assembled consistently due to shifts in the HTS codes. Countries examined included Brazil (26101 m^3/month from January 2000 to April 2008), China (90305 m^3/month), Ecuador (3969 m^3/month), Indonesia (41203 m^3/month), Malaysia (37663 m^3/month), and Taiwan (2871 m^3/month). Monthly imports from Canada, used as a cointegrating quantity or price series in estimating models 2A), (2B), (4A) and (4B), averaged 39299 m^3/month over this same time span. Although important growth in imports of tropical hardwood plywood from Vietnam and Paraguay has occurred in recent years, data prior to the implementation of the LAA were insufficient to allow estimation of statistical models for these countries. The time series of these hardwood lumber unit values (prices) and quantities are shown in Fig. 4a and b, respectively. As is apparent in figures, U.S. imports from China substantially increased from 2005, becoming the largest single import source of this category of plywood. Finally, we note here that none of the imported products included in our analysis were made from coniferous species.

3. Results

The decision on whether an import price or an import quantity can be used in estimates of any of our empirical models is first based on a test of stationarity. For this, we employed the augmented Dickey–Fuller (ADF) test (Dickey and Fuller, 1984), with the augmentation (included lagged difference terms) determined by the lag order yielding the minimum of the Schwarz Information Criterion. Price and quantity variables were tested using the pre-LAA time series, through April, 2008, prior to the implementation of the LAA, to avoid biasing the test in favor of nonstationarity brought about by the shock of LAA implementation. We find that prices and quantities of lumber and plywood imports vary in their time series characteristics, some stationary, some nonstationary, and this also depends sometimes on whether products are transformed by the natural logarithm (Table 2). The time series of these prices and quantities varied in length, due to variations in the length of continuous nonzero import quantities across source countries and on definition changes that occurred part way through the time series. Some results of these ADF tests stand out. For example, quantities of keruing lumber (4407.29.0116) from Malaysia and Indonesia were stationary, while prices were nonstationary for both countries in their untransformed state but stationary for Indonesia when log-transformed. Balsa (4407.21.0006) from Ecuador was found to have stationary prices but not quantities. Teak (4407.29.0131) from Malaysia had stationary prices and quantities. Other hardwood lumber (4407.99) from all countries were judged to have stationary prices and quantities in virtually every case (except prices from Peru). Nonstationary series, potentially permitting cointegration approaches, were found for Bolivian mahogany (4407.21.0000) prices, Ecuador balsa quantity, keruing prices from Malaysia, and other hardwood quantities from Peru. Canadian hardwood lumber prices and quantities (4407.99-

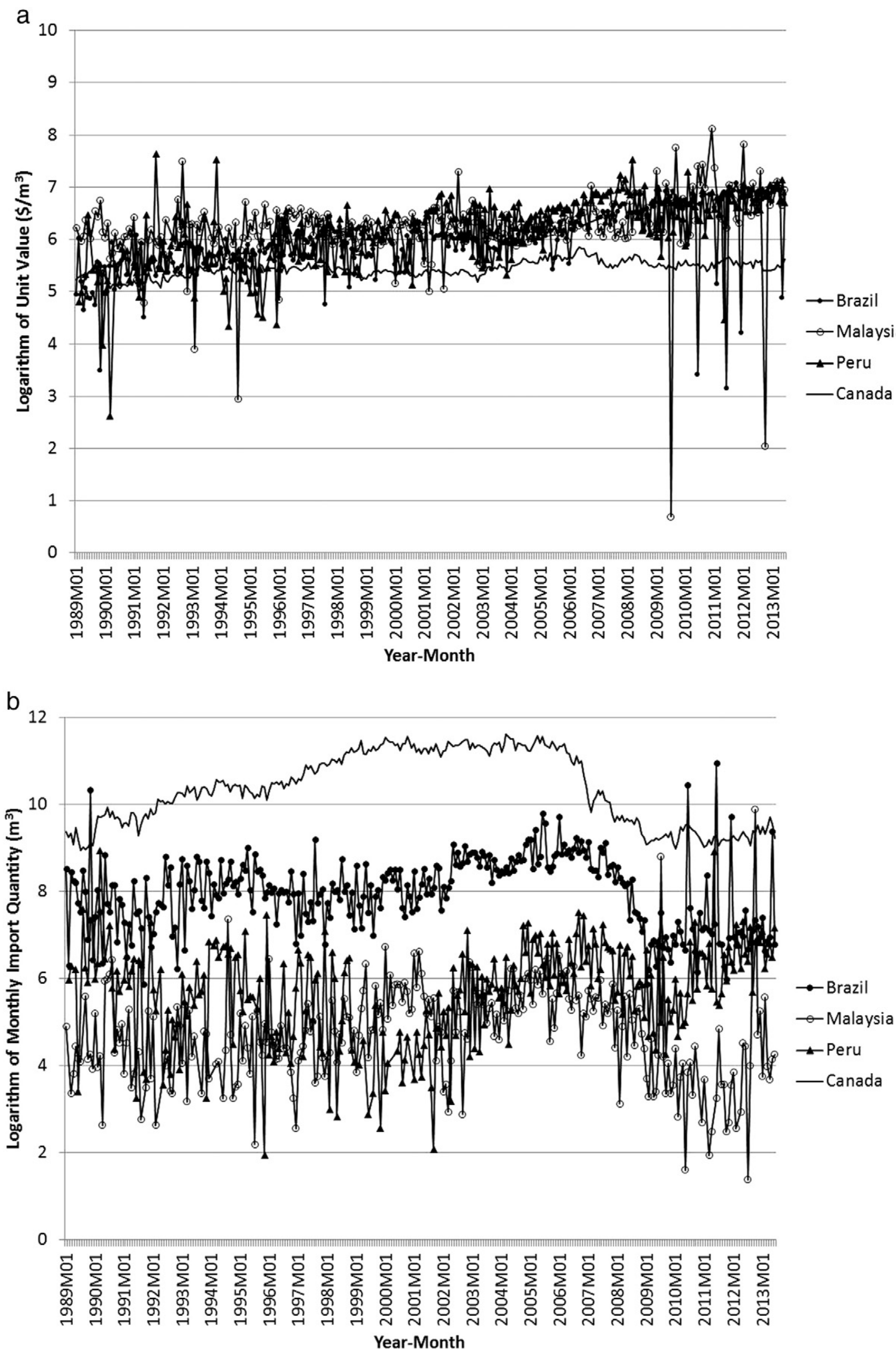
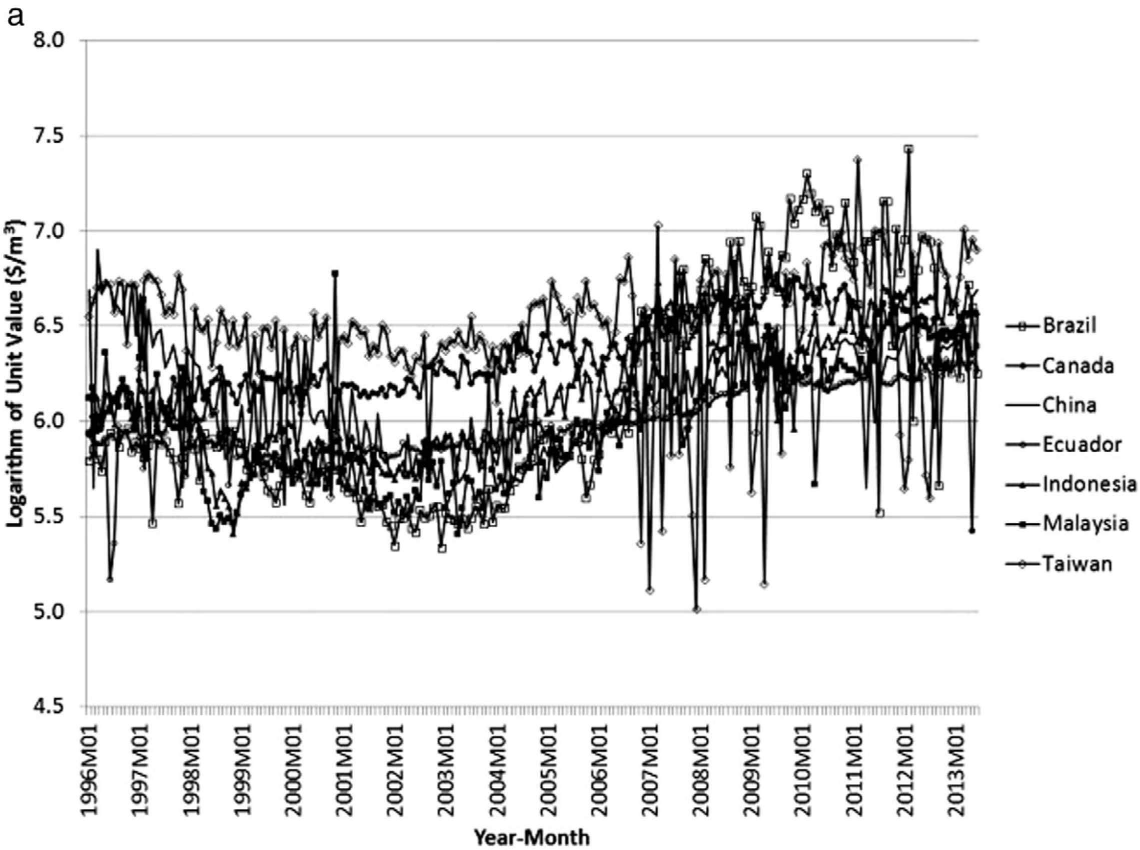


Fig. 3. Natural logarithm-transformed U.S. monthly imports of (a) unit value (US$/cubic meter) and (b) quantity (cubic meters) of other hardwood lumber (4407.99) from Brazil, Malaysia, Peru, and Canada.



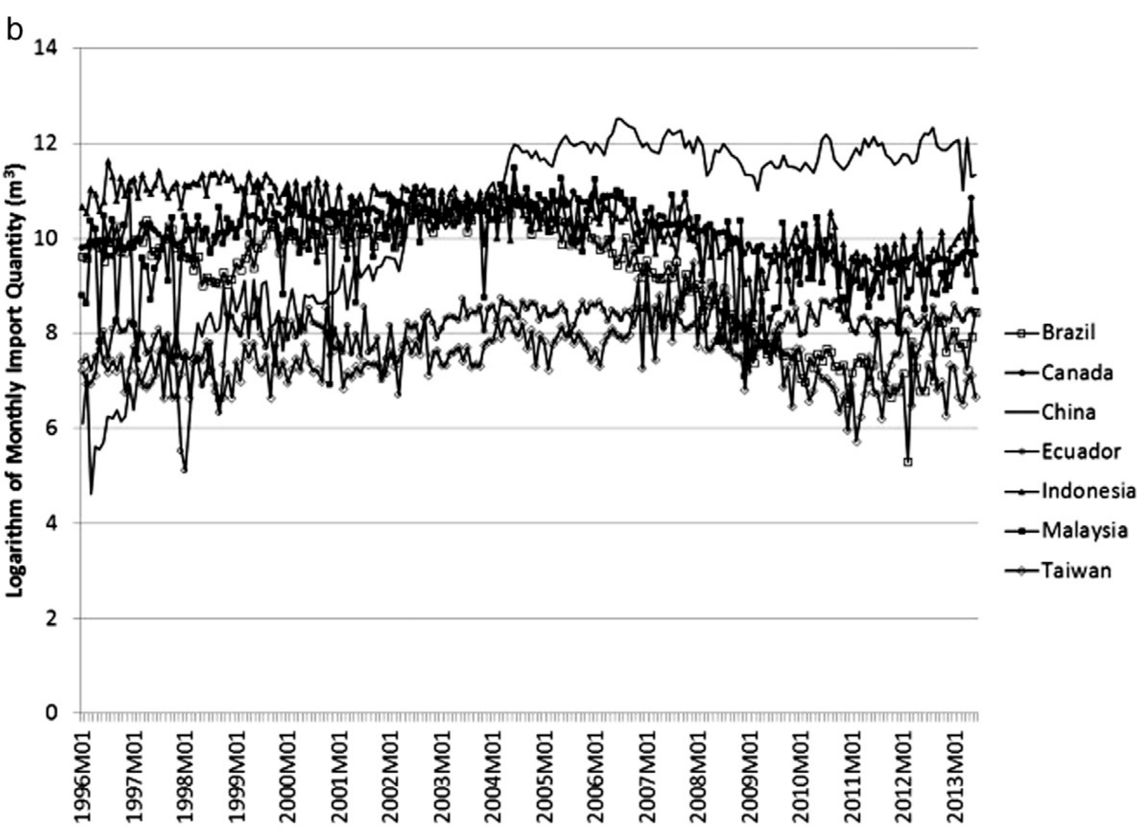


Fig. 4. Natural logarithm-transformed U.S. monthly imports of (a) unit value (US$/cubic meter) and (b) quantity (cubic meters) of hardwood plywood (4412) from Brazil, China, Ecuador, Indonesia, Malaysia, Taiwan, and Canada.

Table 2
Augmented Dickey–Fuller test statistics (ADF test stat.), statistical significances (Signif.), the numbers of lagged difference terms included (ADF order) and observations used (Obs.) for prices and quantities of selected lumber and hardwood plywood products imported to the United States from countries evaluated.

Product HTS code	Product common name	Measure	Source country	ADF test stat.	Signif.	ADF order	Obs.	ADF test stat.	Signif.	ADF order	Obs.
				Unlogged	Unlogged	Unlogged	Unlogged	Logged	Logged	Logged	Logged
4407.21.0000	Mahogany	P	Bolivia	−0.11	0.95	5	202	−1.41	0.57	4	206
4407.21.0000	Mahogany	Q	Bolivia	−2.19	0.21	7	224	−4.88	0.00	2	214
4407.21.0000	Mahogany	Q	Brazil	−4.86	0.00	1	230	−5.66	0.00	0	170
4407.21.0000	Mahogany	P	Peru	−0.37	0.91	8	170	−3.52	0.01	2	186
4407.21.0000	Mahogany	Q	Peru	−1.74	0.41	6	225	−0.24	0.15	4	185
4407.22.0006	Balsa	P	Ecuador	−3.45	0.01	2	229	−4.04	0.00	2	229
4407.22.0006	Balsa	Q	Ecuador	−1.10	0.72	2	229	−1.36	0.60	2	229
4407.22.0091	Imbuia + Baboen	P	Brazil	−5.54	0.00	2	229	−7.80	0.00	1	230
4407.22.0091	Imbuia + Baboen	Q	Brazil	−3.74	0.00	3	228	−3.11	0.03	4	227
4407.29.0116	Keruing	P	Indonesia	−2.11	0.24	2	200	−3.81	0.00	2	200
4407.29.0116	Keruing	Q	Indonesia	−4.01	0.00	2	229	−2.30	0.17	2	200
4407.29.0116	Keruing	P	Malaysia	−1.28	0.64	4	227	−1.82	0.37	4	227
4407.29.0116	Keruing	Q	Malaysia	−5.06	0.00	2	229	−4.80	0.00	2	229
4407.29.0131	Teak	P	Malaysia	−8.60	0.00	0	115	−9.43	0.00	0	115
4407.29.0131	Teak	Q	Malaysia	−11.65	0.00	0	136	−8.91	0.00	0	115
4407.99	Temperate	P	Canada	−2.13	0.23	1	230	−2.29	0.18	1	230
4407.99	Temperate	Q	Canada	−1.11	0.75	4	227	−1.60	0.48	1	230
4407.99	Tropical	P	Brazil	−4.58	0.00	1	230	−4.54	0.00	1	222
4407.99	Tropical	Q	Brazil	−2.33	0.16	6	225	−3.21	0.02	3	228
4407.99	Tropical	P	Malaysia	−5.97	0.00	1	197	−13.14	0.00	0	207
4407.99	Tropical	Q	Malaysia	−7.16	0.00	1	230	−5.64	0.00	1	197
4407.99	Tropical	P	Peru	−1.02	0.74	3	141	−0.97	0.76	0	153
4407.99	Tropical	Q	Peru	−4.34	0.00	3	228	−5.13	0.00	1	167
4412.xx	Hardwood	P	Brazil	1.54	1.00	6	141	−0.07	0.95	1	146
4412.xx	Hardwood	Q	Brazil	−2.22	0.20	1	146	−1.79	0.39	1	229
4412.xx	Hardwood	P	Canada	−0.33	0.92	4	143	−1.36	0.60	2	145
4412.xx	Hardwood	Q	Canada	−2.46	0.13	1	146	−2.95	0.04	0	230
4412.xx	Hardwood	P	China	−2.55	0.11	3	144	−1.94	0.31	3	144
4412.xx	Hardwood	Q	China	−0.81	0.81	12	135	−2.30	0.17	2	145
4412.xx	Hardwood	P	Ecuador	−3.12	0.03	2	145	−3.80	0.00	2	145
4412.xx	Hardwood	Q	Ecuador	−2.86	0.05	2	145	−2.11	0.24	1	143
4412.xx	Hardwood	P	Indonesia	−0.75	0.83	2	145	−0.86	0.80	2	145
4412.xx	Hardwood	Q	Indonesia	−1.67	0.44	2	145	−0.99	0.76	2	145
4412.xx	Hardwood	P	Malaysia	−3.00	0.04	2	145	−2.48	0.12	2	145
4412.xx	Hardwood	Q	Malaysia	−2.90	0.05	3	144	−3.04	0.03	3	144
4412.xx	Hardwood	P	Taiwan	−5.63	0.00	1	146	−5.51	0.00	1	146
4412.xx	Hardwood	Q	Taiwan	−2.92	0.05	2	145	−2.85	0.05	2	145

temperate species component) indicated that all were nonstationary. Hardwood plywood (4412.xx) prices and quantities were more commonly found to be nonstationary, although not for Ecuador, Malaysia, or Taiwan. For purposes of the cointegration approach, Canadian hardwood plywood prices and quantities were all found to be nonstationary.[6]

For brevity and ease of exposition, we limit the results reported in the remaining table (Table 3) of this analysis to those showing the magnitude and significance of the LAA shock effect. We report price and quantity effects as counterfactuals, in percentage terms. That is, percentage change is relative to what the average monthly price or quantity of the import would have been had the LAA not been enacted, calculated from June of 2008 through June of 2013. Detailed results of all equation estimates are available from the author upon request. The table header shows four versions of the stationary model, where A corresponds with Eq. (1) and B, C, and D correspond with progressively more inclusive stationary models (from Eq. (3)) which were meant to test for the effects of other hypothesized important factors affecting prices or quantities. Models of prices and quantities using cointegration methods are labeled as E, corresponding with Eqs. (2A) and (2B) and F, corresponding to Eqs. (4A) and (4B). It is important to note that not all combinations of prices and quantities and their transformations are included for all countries. This was because certain country-product nonstationary prices or quantities were not cointegrated with the comparison series (Canadian lumber or hardwood plywood), rendering these time series inappropriate for estimation with these nonstationary intervention modeling approaches.

Most 10-digit and 6-digit (4407.99-other hardwood, only for Brazil, Malaysia and Peru) lumber price and quantities recorded statistically significant increases in prices and decreases in quantities, as hypothesized, consistent with a backwards shift in the export supply curve from the suspected source countries (Fig. 1).[7] Typically, prices have been higher since the advent of the LAA by about 40% and quantities lower by nearly double that amount, and this is irrespective of the method used or the various levels of additional explanatory variables included in the analyses.[8] This result (lower price effect than quantity effect) indicates a broadly elastic response of demand to the source country imports. Overall, the inclusion of additional explanatory variables (U.S. housing

6 Seneca Creek Associates (2004) does not separately list Taiwan as a country with possible production of illegally sourced wood fiber products. We include it in this study because of the potential that its levels of such production are similar to that reported as "China" in that study.

7 Statistical models estimate the size of the LAA shock dummy parameter (λ), shown in Eqs. (1)–(4B). The percentage changes are first calculated by calculating the long-run effect of the LAA shock: dividing the LAA dummy parameter estimate by 1 minus the sum of the coefficients on the lagged dependent variable: $\hat{\lambda}_{LR} = \hat{\lambda}/\left(1-\sum_{j=1}^{J}\hat{\alpha}_{1,j}\right)$. For example, if one lagged dependent variable were included in Eqs. (1), (2B), (3), or (4B) and its value was $\hat{\alpha}_{1,1} = 0.3$, then the long-run shock parameter estimate would be $\hat{\lambda}_{LR} = \hat{\lambda}/(1-0.3)$.

8 The addition of exchange rates in the stationary and the cointegration models usually increased the explanatory power of the estimated models. Exchange rates were found to be significant explainers of shifts in prices and quantities imported, indicating that passthrough was incomplete. For the stationary price and quantity models, these findings emerged for balsa lumber from Ecuador; mahogany lumber from Bolivia; imbuia–baboen lumber from Brazil, keruing from Indonesia; teak from Malaysia; and other hardwoods (4407.99) from Brazil and Malaysia; and hardwood plywood imports from Ecuador, Malaysia and Taiwan.

Table 3
Estimated effects of the LAA on hardwood lumber and hardwood plywood import untransformed and natural logarithm-transformed prices (P) and quantities (Q) measures, percent change compared to what prices would have averaged, June of 2008 to June of 2013, without the LAA in place, according to the statistical model used: stationary univariate (Stat. univar.) and nonstationary series' cointegrating relation (Coint. rel.) approaches.

Current HTS code	Country	Measure	Stat. univar.	Stat. univar.	Stat. univar.	Stat. univar.	Coint. rel.	Coint. rel.
			(A)	(B)	(C)	(D)	(E)	(F)
				(A) + exchange rate	(B) + U.S. housing starts, U.S. real GDP	(C) + China real GDP		(E) + exchange rates
4407.21.0000	Bolivia	P					21.54***	26.94***
4407.21.0000	Bolivia	Ln(P)					28.70***	33.49***
4407.21.0000	Bolivia	Q					−91.71***	−92.52***
4407.21.0000	Bolivia	Ln(Q)	−67.34**	−79.44***	−78.75***	−78.75***		
4407.21.0000	Peru	P					12.13*	7.37
4407.21.0000	Peru	Ln(P)	8.29+	8.82+	8.88	8.91+		
4407.21.0000	Peru	Q					n.c.[a]	n.c.[a]
4407.21.0000	Peru	Ln(Q)					−35.78+	−49.92**
4407.22.0006	Ecuador	P					91.56***	70.09***
4407.22.0006	Ecuador	Q						−15.59
4407.22.0006	Ecuador	Ln(Q)						4.43
4407.22.0091	Brazil	P	5.88	7.87	39.78***	40.46***		
4407.22.0091	Brazil	Ln(P)	36.32***	41.22***	40.44***	40.54***		
4407.22.0091	Brazil	Q	−74.78**	−71.64+	−71.18+	−71.29**		
4407.22.0091	Brazil	Ln(Q)	−62.33*	−62.85*	−63.75*	−63.56*		
4407.29.0116	Indonesia	Ln(P)	−42.76**	−34.17*	−36.34	−36.37**		
4407.29.0116	Indonesia	Q	−76.89	−82.40**	−83.90	−83.90**		
4407.29.0116	Malaysia	P					61.38***	77.14***
4407.29.0116	Malaysia	Ln(P)					59.68***	72.82***
4407.29.0116	Malaysia	Q	−35.71***	−35.85***	−40.60**	−37.05***		
4407.29.0116	Malaysia	Ln(Q)	−36.25+	−35.57+	−35.57*	−36.65+		
4407.29.0131	Malaysia	P	67.53***	89.43***	103.63***	97.46***		
4407.29.0131	Malaysia	Ln(P)	93.19***	179.80***	184.31***	183.68***		
4407.29.0131	Malaysia	Q	−86.37**	−86.76***	−87.61***	−87.63***		
4407.29.0131	Malaysia	Ln(Q)	−58.21***	−84.06***	−84.64***	−84.62***		
4407.99	Brazil	P	68.12***	66.23***	68.71***	67.61***		
4407.99	Brazil	Ln(P)	30.40*	29.81***	30.71**	30.58**		
4407.99	Brazil	Q					−47.43***	−50.11***
4407.99	Brazil	Ln(Q)	−79.78***	−79.77***	−79.74***	−79.71***		
4407.99	Malaysia	P	94.07***	93.72***	95.31***	95.36***		
4407.99	Malaysia	Ln(P)	85.28***	85.24***	87.24***	87.37***		
4407.99	Malaysia	Q	−68.41***	−68.01***	−68.51***	−68.34***		
4407.99	Malaysia	Ln(Q)	−66.93***	−67.12***	−68.04***	−68.05***		
4407.99	Peru	P					33.46*	−7.42
4407.99	Peru	Ln(P)					0.43	23.20
4407.99	Peru	Q	60.87	67.85+	60.41	58.21		
4407.99	Peru	Ln(Q)	39.43	39.63	29.94	29.88		
4412.xx	Brazil	P						42.76***
4412.xx	Brazil	Ln(P)						38.82***
4412.xx	Brazil	Q						−75.37***
4412.xx	China	P						−7.22
4412.xx	China	Ln(P)						−20.51+
4412.xx	China	Q						−13.70**
4412.xx	Ecuador	P	39.63***	37.53***	36.58***	36.61***		
4412.xx	Ecuador	Ln(P)	39.72***	37.83***	37.23***	37.25***		
4412.xx	Ecuador	Q	6.12	−4.28	−3.72	−4.03		
4412.xx	Ecuador	Ln(Q)					29.96***	
4412.xx	Indonesia	P					0.86	8.92+
4412.xx	Indonesia	Ln(P)					11.11	15.23**
4412.xx	Indonesia	Q						−64.31***
4412.xx	Malaysia	P	64.82***	38.00***	34.78***	34.80***		
4412.xx	Malaysia	Ln(P)					51.99***	18.42***
4412.xx	Malaysia	Q	−67.95***	−59.83***	−58.53**	−58.63**		
4412.xx	Malaysia	Ln(Q)	−69.52***	−61.38***	−61.38***	−59.72***		
4412.xx	Taiwan	P	22.99**	12.08	9.68	8.43		
4412.xx	Taiwan	Ln(P)	22.18+	8.64	5.45	5.08		
4412.xx	Taiwan	Ln(Q)	−37.03*	−27.32	−22.07	−21.71		
4412.xx	Taiwan	Q	−44.00	−24.57	−19.97	−17.41		

Note: + indicates significance at 20%, * at 10%, ** at 5%, and *** at 1%.
[a] Not calculated because the estimated quantity change was larger than the post-LAA average quantity observed; essentially, imports of this product have been driven to near zero.

starts, U.S. real GDP, and China real GDP) had negligible effects on the magnitude of the price or quantity changes post-LAA. The largest price change recorded was for teak lumber from Malaysia (increasing by about 180%). The smallest statistically significant price effect was for Peruvian mahogany (8 to 12%, depending on the model), although this effect was statistically weak. The largest reduction in quantity corresponding with LAA implementation was found for Bolivian mahogany (about −92%, obtained using the cointegration approach). One statistically significant result that was counter to expectations was the negative price effect found for keruing from Indonesia, which in the model corresponding to Eq. (1) exhibited a drop of about 40%. The quantity of that product imported by the U.S. similarly demonstrated a drop (by about 80%), which did fit expectations.

For hardwood plywood, results (the bottom part of Table 3) show support for a contention that the LAA has affected both prices and quantities of imports. The import price from Brazil increased approximately 40% and quantity decreased about 75%. Imports from China decreased by 14 or 21%, although no significant price effects could be found; such a result could indicate that a more detailed model of the changes in the Chinese market could yield more insights. Prices for hardwood plywood imports from Ecuador increased an average of about 40% across all models estimated, although no significant quantity effects could be identified. Imports from Indonesia have increased in price and fallen in quantity, again with the quantity decrease more than double the estimated price increase. A similar phenomenon is found for hardwood plywood imports from Malaysia, with price increases of about 30% and quantity decreases that were approximately double that. Imports of hardwood plywood from Taiwan have demonstrated weak evidence of a price increase in most cases and also weak evidence of a quantity decrease, with estimated quantity decreases about 1.5 times larger than the price increase.

Not shown in Table 3 are estimates of the effects of the additional explanatory variables related to legal or policy changes affecting the source countries for some products imported by the U.S. from Bolivia, Peru, Brazil, and Indonesia. The results of the statistical models, however, indicate that these policies and laws broadly have had the effects on prices and quantities anticipated. We find that the CITES III listing had a statistically significant (at traditional significance levels) negative effect on the quantity of U.S. imports of mahogany imports from Bolivia (suggesting a backwards export supply shift), while the CITES II listing had a positive effect on the import price from Peru (also consistent with a backwards export supply shift). For hardwood lumber imports from Brazil, we find that the passage of the 80% forest retention law (modeled as beginning in January of 1996) had a positive effect on the quantity of U.S. imports of imbuia–baboen and a negative effect on the price of those imports—opposite of what would have occurred with a contraction of supply. However, the law's passage had a positive effect on the import price of other hardwood lumber (4407.99) imported from Brazil, which was consistent with a supply contraction. The law's implementation (modeled as starting in January of 2001) had a positive effect on the price of imports of imbuia–baboen (as expected) but a positive effect on the quantity of other hardwood lumber imports. The upped law enforcement effort (modeled as starting in January of 2005) had the expected positive effect on price and negative effect on quantity of imbuia–baboen imports. Indonesia's PI-04 (effective from 2005) was found to have a positive effect on the U.S. import price and a negative effect on the import quantity of keruing (4407.29.0116) from that country, consistent with expectations. The Timber Legality Verification System (SVLK) (from mid-2009 onward) appears to have had a negative price effect and a weakly positive quantity effect on the imports of hardwood plywood from Indonesia, which are both counter to expectation. The Indonesian moratorium on natural forest concessions (from mid-2011), on the other hand, is connected statistically to a positive price effect for keruing and hardwood plywood imports from Indonesia, consistent with expectations.

Finally, we note that the logarithmic transformation of prices and quantities, a common approach in economic studies of supply and demand, generally had little effect on the estimated price or quantity changes corresponding with the implementation of the LAA. In cases where logarithmic transformations could be compared with series without transformation, with a few exceptions, differences in results tended to be in single digit percentage points. Significances were also rarely affected.

4. Conclusions

Timber product manufacturers and landowners in the U.S. and worldwide have been concerned about the effects of illegal logging on their market prices and market shares, domestically and in international trade. Environmental organizations and individuals worldwide are also distressed at the negative effects that illegal logging and other sorts of illegal fiber sourcing have on forests and the rule of law in places where these activities occur. Governments have taken action worldwide by a variety of means, from enhanced law enforcement efforts, institution building, limits on natural forest harvests in the source countries, and enactment of trade measures. The Lacey Act Amendment of 2008 is a trade measure that sought to discourage the trade in illegally obtained plant products including wood, thereby indirectly affecting the incentives that producers in suspected countries face, possibly reducing the rate of illegal fiber sourcing. We find, applying two classes of statistical models that alternately exclude and include important macroeconomic factors (exchange rates, construction activity, overall economic output, and the growth in China's economy) while controlling for the effects of important laws and policies related to supply in some suspected source countries, which would also be expected to affect trading incentives, that they might indeed have affected producers' incentives; the prices of lumber and hardwood plywood imports into the U.S. from suspected illegal fiber source countries have increased and their quantities have decreased upon enactment of the LAA.[9] Both price and quantity effects are consistent with a backwards shift in export supply of these products from these countries, which we posit would be the effect of removing illegally produced wood from the supply offered to the United States. These effects potentially could be perceived as a benefit for those advocating for the rule of law when it comes to fiber sourcing and for those seeking relief—the producers of legal wood products in the source country and in the U.S.—from competition from illegally sourced wood. Legal producers now face higher prices, while illegally sourced fiber faces a smaller level of demand in the international market. The results, which demonstrate quantity decreases that typically are double the price increases found for most products and countries examined, are consistent with an elastic demand response to a backwards-shifting foreign supply. These findings are evidence that the LAA has met some of its advocates' objectives.

The results on the effects of the LAA, accompanied by the findings related to the effects of CITES appendix listing for mahogany relevant to Bolivia and Peru and legal and policy changes in Brazil and Indonesia, add statistical evidence that bolsters the indicators listed by Lawson and McFaul (2010). Specifically in the case of Brazil, these authors noted substantial improvements in forest management and enforcement activities in Brazil in the latter half of the 2000s, which corresponded with LAA implementation as well as the enforcement efforts focused on limiting natural forest clearing.

Although the analyses reported in this research may have successfully detected and accurately quantified the effects of the LAA on U.S. imports of some lumber products and hardwood plywood from suspected source countries with whom the U.S. has had significant trade, it should be noted that such trade measures have other, indirect effects that still need to be further studied before policy makers can judge the LAA as a complete success at reducing illegal fiber sourcing in all markets. First and foremost is to understand to what extent illegal producers have diverted their illegally sourced fiber exports away from the U.S. and toward third countries without such trade measures. Second, substitution can happen within countries suspected of illegal sourcing, wherein those countries' exporters now export only legal fiber and divert the illegal production toward domestic consumers. The specific efforts of some countries,

[9] A separate analysis, recommended by an anonymous reviewer, evaluated how model fit and the measured percent effect of the LAA on prices and quantities would be influenced by different hypothesized starting months; such shifts might have been induced by the varying starting dates for required submission of import declaration form PPQ505 following the LAA enactment. The start month was varied from 12 months before to 12 months after June of 2008. According to the Akaike Information Criterion, statistical fit was highest with an average lag of 2 or 3 months (effects beginning in August or September, 2008), with variation across countries (from a lead of 2 months to a lag of 6). However, the measured long-run price and quantity changes corresponding to the LAA differed by only a few percentage points from the values reported in Table 3.

including Brazil and Indonesia, focused on preventing (illegal and legal) domestic production from natural forests are, according to our analysis, an effective response to this, however. Both trade diversion and domestic consumption shifts in response to a policy are a form of policy "leakage," in the parlance of policy analysis. Until the possible leakage effects of the LAA and similar measures such as EU Regulation 995 are better understood, and until we more firmly establish the design of the most effective domestic strategies for limiting illegal sourcing in suspected source countries that complement the U.S. and EU trade measures, judgment should be withheld about their overall, long-run effects and effectiveness in achieving reductions in illegal fiber sourcing.

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