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DETECTING ILLEGAL TRADE PRACTICES BY ANALYZING DISCREPANCIES IN FOREST PRODUCTS TRADE STATISTICS

AN APPLICATION TO EUROPE, WITH A FOCUS ON ROMANIA

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Abstract

Discrepancies in bilateral trade statistics for forest products have recently attracted attention as potential indicators of illegal trade practices. For example, if exporters understate quantities in order to evade export taxes or quotas, then one might expect reported exports to be less than reported imports. Discrepancies in trade statistics can exist for reasons that have nothing to do with illegal activities, however, such as measurement error and shipment lags. Any attempt to infer evidence of illegal activities from statistical discrepancies must control for these other explanations.

The mean discrepancy for sawnwood exported by Romania during 1982-97 was significantly different from zero for coniferous sawnwood but not for nonconiferous sawnwood. Yet, the sign of the discrepancy for coniferous sawnwood—reported exports tended to be greater than reported imports—implies that illegal trade activities were more likely occurring in Romania's trading partners than in Romania.

An econometric analysis of bilateral trade statistics for Romania and other European countries found evidence that measurement error, shipment lags, and intentional underreporting all play a role in explaining discrepancies for both types of sawnwood. The econometric model is not sufficiently reliable, however, for estimating the portion that was due solely to illegal activities or determining whether those activities occurred primarily in Romania or in it trading partners. Moreover, given that it is based on observed discrepancies in bilateral trade statistics, it fails to detect illegal trade activities that occur simultaneously in both importing and exporting countries. For these reasons, econometric methods appear unlikely to be of practical use in revealing illegal trade activities in the Romanian forest sector.

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Jeffrey R. Vincent[2]

1 Introduction

Corrupt and illegal activities in the global forest sector have come increasingly into the spotlight during the past few years. This report focuses on one subset of these activities: the intentional underreporting of imports and exports of forest products. It considers whether the amount of intentional underreporting can be inferred from observed discrepancies between the amounts officially reported as imported and exported by trading partners. It pays special attention to trade involving Romania.

It is well-known among trade economists that import and export statistics rarely match up exactly (Lichtenberg 1959, Woolley 1966, Feenstra et al. 1999, Feenstra and Hanson 2000, Feenstra 2000). Trading partners often report very different physical quantities and values for the products they trade between each other. These discrepancies have several possible explanations. Some explanations, like measurement error, are innocuous. Exports are especially prone to measurement error. Customs offices often make only a perfunctory effort to monitor exports because, unlike imports, exports are seldom subject to customs duties. Discrepancies can also occur due to shipment lags. For example, a cargo liner that leaves an exporting country late one year might not arrive in the importing country until early the following year, thus leading to a discrepancy in the two countries' annual bilateral trade statistics. In the case of value data, one would always expect imports to exceed exports for the simple reason that import values include the costs of insurance and freight on top of the value of goods at the point of export.

Another possible explanation is that discrepancies reflect illegal activities, such as smuggling and underinvoicing (Pritchett and Sethi 1994, Fisman and Wei 2001). This explanation has attracted substantial attention recently among organizations interested in the international forest sector.[3] It was spotlighted, for example, in a recent issue of the International Tropical Timber Organization's *Tropical Forest Update* (volume 12, number 1, 2002), which focused on forest crime. An article in that issue noted the existence of persistent discrepancies between reported imports and exports for certain products and trading partners, such as industrial roundwood traded from Indonesia to China and sawnwood traded from Malaysia to Japan (Johnson 2002). The same article acknowledged, however, that "problems in statistical reporting together with legitimate reasons for discrepancies between trading partner reports may reduce the utility of such analyses for identifying potentially illegal trade flows" (p. 6).

In this report we develop an econometric method for disentangling the various possible explanations for statistical discrepancies in bilateral trade flows of forest products. The method is

[2] Jim Anderson, Nalin Kishor, and Peter Dewees provided extensive and insightful comments on an earlier draft of this paper. I am grateful to them and am fully responsible for any errors that remain.

[3] This attention is not entirely new. See Durst et al. (1986).

applied to data on trade flows that involve European countries as either importers or exporters. The report focuses on trade in sawnwood (i.e., lumber), which is the principal primary forest product exported by Romania. It examines discrepancies in physical quantities traded, not the value of trade. By focusing on physical quantities, the analysis avoids the confounding effects of insurance and freight costs on import data and exchange rate fluctuations on both import and export data.

The report is organized as follows. We begin by describing the source of trade flow data for the analysis, the EFI/WFSE Trade Flow Database.[4] We then describe a relative measure of discrepancies in trade statistics that we developed based on those data. Next, we provide descriptive statistics on the magnitude of discrepancies for Romanian imports and exports. We gauge the magnitude of these discrepancies by comparing them to discrepancies for other European countries. The purpose of this comparison is to determine whether discrepancies in trade statistics are unusually large or small when Romania is one of the trading partners compared to when it is not. We find that Romania's discrepancies are large by European standards in the case of exports of coniferous sawnwood and imports of nonconiferous sawnwood. In both cases, however, the signs of the discrepancies suggest that, to the extent the discrepancies reflect illegal trade activities, those activities are more likely occurring in Romania's trading partners than in Romania itself.

Following this descriptive analysis, we turn to the econometric analysis, which seeks to identify the relative importance of the various potential explanations of these discrepancies. We first present a theoretical model that provides guidance on the choice of explanatory variables to include in an econometric model of discrepancies in trade statistics. We test the significance of these explanatory variables by analyzing data for 1982-97 pooled across European countries, not just Romanian data. We find statistical support for several of the potential explanations of the discrepancies, including intentional underreporting of imports and exports. The explanatory power of the model is poor, however, and the coefficients on several key explanatory variables are statistically insignificant or have the incorrect signs. For these and other reasons, we conclude that the practical usefulness of econometric methods for detecting illegal trade practices in the Romanian forest sector is likely to be limited.

2 Data on trade statistics discrepancies

2.1 The EFI/WFSE Trade Flow Database

The EFI/WFSE Trade Flow Database was developed by the European Forest Institute (EFI).[5] It contains annual data on physical quantities and values of imports and exports of forest products for all countries in the world, not just those in Europe. It is, to our knowledge, the best available database on forest products trade flows.

The EFI Database is based on standard COMTRADE data from U.N. Statistics Division. In addition to the original COMTRADE data series, which it stores in a variable named QORIG, the

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4 We are grateful to the European Forest Institute, Mr. Bruce Michie in particular, for granting access to the data. We are also grateful to Kevin O'Connell and Max Auffhammer of the University of California at San Diego for their assistance in converting the data to a form readable by STATA and to O'Connell for his assistance in an exploratory analysis that preceded this one.

5 For more information, see the webpage for the database: http://www.efi.fi/efidas/fpstf.html.

EFI Database also includes a "cleaned" series, in a variable named QUANTITY. As part of the data cleaning process, EFI staff standardized measurement units—in particular, they converted all physical quantities to cubic meters—and corrected decimal place errors and other obvious mistakes in the QORIG series.[6] In section 2.2 we explain how we used the QUANTITY variable to develop a relative measure of trade flow discrepancies, which served as the dependent variable in our econometric models. In section 5.1 we explain how we used the QORIG variable to develop measures of potential measurement error, which we included in the explanatory variables.

The product categories in the database are relatively broad aggregates of SITC codes. They correspond to the product definitions used by the U.N. Food and Agriculture Organization in its on-line FAOSTAT Forestry database (apps.fao.org/page/collections?subset=forestry). "Sawnwood" is such a category. We selected sawnwood as the focus for our analysis because Romania imports and exports relatively little of other primary forest products. Romania has historically exported a substantial amount of wood furniture, but the EFI Database includes data on trade of wood furniture only for two years, 1999-2000. For most products, including sawnwood, the database includes data separately for nonconiferous (NC) and coniferous (C) products.[7] We analyzed the two subcategories separately. Appendix 1 shows the SITC and U.N. codes included in the NC and C sawnwood product categories in the database.

The EFI Database includes nearly four decades of data, 1962-99. Our analysis covers a shorter period, 1982-97, due to the more limited availability of some of the explanatory variables in the econometric model. The database contains data on Romanian trade flows mainly from 1990 forward. Changes in national boundaries during the 1990s affect the definitions of several Romanian trading partners. The database includes Germany as a single country since 1991 and as two countries, West Germany ("Germany FR") and East Germany ("Germany DR") in prior years. It includes Czechoslovakia, Yugoslavia ("ex-Yugoslavia"), and the Soviet Union ("ex-USSR") as single countries before 1993; from 1993 forward, it includes the Czech Republic, Slovakia, Macedonia, Bosnia and Herzegovina, Croatia, Slovenia, Yugoslavia (i.e, Serbia and Montenegro), and the individual republics of the former Soviet Union (Russian Federation, etc.) as separate countries. It reports data separately for Belgium and Luxembourg only after 1998.

2.2 A relative measure of discrepancies in trade statistics

We developed a relative measure of discrepancies in trade statistics. Denote imports and exports by the following variables:

I^R_{ij} Reported imports by country *i* from country *j*
E^R_{ij} Reported exports by country *j* to country *i*

Then the relative discrepancy is defined as:

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6 They also made an effort to fill in missing data on physical quantities, by dividing data on the value of trade by unit values for other importers or exporters. We excluded these constructed estimates from the data we analyzed.

7 Nonconiferous trees are flowering plants (angiosperms). They are often referred to as broad-leaved or hardwood trees. Coniferous trees are cone-bearing plants (gymnosperms). They are often referred to as needle-leaved or softwood trees.

$$\Delta_{ij} \equiv \frac{I_{ij}^{R} - E_{ij}^{R}}{I_{ij}^{R} + E_{ij}^{R}}. \qquad (1)$$

This measure ranges from –1 to +1. Positive values indicate that the importer reports a larger trade flow than the exporter, and negative values indicate the reverse. The index has the maximum value of +1 when the importer reports a trade flow but the exporter does not ($I^R_{ij} > 0$ and $E^R_{ij} = 0$) and the minimum value of –1 when the opposite conditions hold, i.e. the exporter reports a trade flow but the importer does not ($E^R_{ij} > 0$ and $I^R_{ij} = 0$). It equals zero only when there is no discrepancy ($I^R_{ij} = E^R_{ij}$).

This expression can be reorganized to recover the ratio of reported imports to reported exports:

$$\frac{I_{ij}^{R}}{E_{ij}^{R}} = \frac{1+\Delta_{ij}}{1-\Delta_{ij}} \qquad (2)$$

For example, reported imports are twice as large as reported exports if $\Delta_{ij} = +0.33$ and half as large if $\Delta_{ij} = -0.33$. If $\Delta_{ij} = +0.2$, reported imports are 50 percent larger than reported exports; if $\Delta_{ij} = -0.2$, they are two-thirds as large. If $\Delta_{ij} = +0.1$, reported imports are about 20 percent larger than reported exports; if $\Delta_{ij} = -0.1$, they are about 20 percent smaller.

We constructed this relative measure using the cleaned data series in the EFI Database, QUANTITY. We used it in both the descriptive and econometric analyses described below. In both cases, we constructed the relative discrepancy only when reported imports and reported exports were each at least 100 cubic meters (i.e., $E^R_{ij} \geq 100$ *and* $I^R_{ij} \geq 100$). We did this to ensure greater precision in our estimates (at least three significant digits) and, in the econometric analysis, to reduce errors-in-variables problems (discussed later). Although this selection criterion reduced the number of bilateral flows included in the analysis, it had a negligible impact on the volume of trade analyzed: bilateral flows of less than 100 cubic meters do not account for much of the total volumes of sawnwood imports and exports reported by the countries in the sample.

3 Descriptive analysis

3.1 Romania as an exporter of sawnwood

According to the EFI Database, Romania exported NC sawnwood to 43 countries during 1982-97 and C sawnwood to 35 countries. European countries accounted for nearly two thirds of the trading partners for both products, 26 and 22 respectively. Moreover, trade tended to occur more regularly with European partners—at least, the database included more years of data on them—and tended to be larger in terms of the physical volumes traded. Appendices 2 and 3 list the importers of Romanian NC and C sawnwood. Appendix 4 lists the countries we considered to be “European.”

Table 1 presents summary information on the relative discrepancy, Δ_{ij}, for sawnwood exported by Romania to all of its trading partners, not just those in Europe. In this table and subsequent ones, asterisks (*) indicate the significance levels for tests of equality to zero. The mean discrepancy is negative for both NC and C sawnwood, but it is significantly different from zero only for the latter. The mean value for C sawnwood, –0.119, implies that imports reported by Romania's trading partners were about 20 percent lower than exports reported by Romania.[8]

Table 1. Relative discrepancy (Δ_{ij}) for sawnwood exported by Romania during 1982-97, aggregated across all importing countries. Positive discrepancies indicate that reported imports were greater than reported exports; negative discrepancies indicate the reverse.

Product	*Number of observations*	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
NC sawnwood	129	–0.034	0.367	–0.997	+0.952
C sawnwood	124	-0.119^{***}	0.377	–0.997	+0.989

Notes: a. Romanian trade flows in the EFI Database are mainly for the 1990s.
b. Sample includes only trade flows with reported imports and exports both ≥ 100 m^3.
c. ***,**,*: mean is significantly different from zero at 1%, 5%, 10% level.

The standard deviations and the minimum and maximum values in Table 1 indicate that there was considerable variation in the discrepancies across the trade flows in the sample. Table 2 presents additional information on this variation. It shows mean discrepancies by importing country. It includes only countries for which the EFI Database includes at least five years of data (not necessarily consecutive) on imports from Romania. In the case of NC sawnwood, the mean discrepancy is significantly different from zero at a 5-percent level in just two cases, Sweden and the United Kingdom. The discrepancies are negative: imports reported by these two trading partners are smaller than the exports reported by Romania, especially when Sweden is the importer. The discrepancy of –0.324 indicates that Sweden's reported imports are about half as large on average as Romania's reported exports. In the case of C sawnwood, the mean discrepancy is significantly different from zero at a 5-percent level for just Saudi Arabia, but it is enormous: –0.756, which implies that imports reported by Saudi Arabia were on average just 14 percent of the exports reported by Romania.

In sum, for both products we find little evidence of large and statistically significant discrepancies with most trading partners. The exceptions are exports of NC sawnwood to Sweden and the United Kingdom and exports of C sawnwood to Saudi Arabia. Mean discrepancies are moderate to large (≤ –0.1 or ≥ 0.1) for a few other countries for both products but are not significantly different from zero at a 5-percent level, although this could be because the number of observations is so small. Note that the maximum number of observations in the table is only 9.

Table 2. Relative discrepancy (Δ_{ij}) for sawnwood exported by Romania during 1982-97, disaggregated by importing country. Positive discrepancies indicate that reported imports were greater than reported exports; negative discrepancies indicate the reverse. Table shows only countries with 5 or more observations.

Country	*NC sawnwood*	*C sawnwood*

8 From equation (2), Δ_{ij}, = –0.119 implies a ratio of reported imports to reported exports of (1–0.119)/(1+0.119), which equals 0.787: reported imports are approximately 20% (precisely, 21.3%) lower than reported exports.

	Number of observations	*Mean discrepancy*	*Number of observations*	*Mean discrepancy*
Austria	5	–0.008	6	–0.088
Cyprus	5	0.138	-	-
Egypt	-	-	8	0.269^{*}
Germany	5	0.095	9	–0.019
Greece	9	–0.061	9	–0.035
Israel	5	–0.092	8	–0.233
Italy	8	0.131^{*}	6	–0.032
Morocco	8	–0.061	9	–0.035
Netherlands	6	0.101	-	-
Saudi Arabia	-	-	5	-0.756^{***}
Spain	7	–0.037	-	-
Sweden	7	-0.324^{***}	-	-
Switzerland	-	-	6	–0.059
Tunisia	5	0.096	-	-
Turkey	-	-	9	–0.096
United Kingdom	8	-0.123^{**}	-	-

Notes: a. Romanian trade flows in the EFI Database are mainly for the 1990s.
b. Sample includes only trade flows with reported imports and exports both ≥ 100 m^3.
c. ***, **, *: mean is significantly different from zero at 1%, 5%, 10% level.

3.2 Romania as an importer of sawnwood

Romania imported sawnwood from a much shorter list of countries during 1982-97: just 17 in the case of NC sawnwood and 13 in the case of C sawnwood. The exporters were overwhelmingly European countries: 13 and 12, respectively. Appendices 5 and 6 list the countries that exported the two products to Romania.

Table 3 presents summary information for imports by Romania, parallel to the information in Table 1 for exports. The first thing to note is that the number of observations is many fewer: Romania is on the receiving end of the sawnwood trade less often than it is on the shipping end. Only the mean for NC sawnwood is significantly different from zero, and it is positive and large: on average, Romania's reported imports of NC sawnwood exceed the amounts reported by its trading partners by about half.

The minimum of five years of data occurred for just one exporting country for both products, Germany. Table 4 shows the mean discrepancies. The mean discrepancy is positive for both products—Romania's reported imports exceed Germany's reported exports—but it is significantly different from zero only for NC sawnwood. The value, 0.656, is very large and implies that imports reported by Romania were on average nearly 4 times larger than the exports reported by Germany.

Table 3. Relative discrepancy (Δ_{ij}) for sawnwood imported by Romania during 1982-97, aggregated across all exporting countries. Positive discrepancies indicate that reported imports were greater than reported exports; negative discrepancies indicate the reverse.

Product	*Number of observations*	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
NC sawnwood	32	0.199**	0.427	–0.690	+0.953
C sawnwood	11	–0.090	0.524	–0.263	+0.442

Notes: a. Romanian trade flows in the EFI Database are mainly for the 1990s.
b. Sample includes only trade flows with reported imports and exports both ≥ 100 m^3.
c. ***, **, *: mean is significantly different from zero at 1%, 5%, 10% level.

Table 4. Relative discrepancy (Δ_{ij}) for sawnwood imported by Romania during 1982-97, disaggregated by exporting country. Positive discrepancies indicate that reported imports were greater than reported exports; negative discrepancies indicate the reverse.

Country	*NC sawnwood*		*C sawnwood*	
	Number of observations	*Mean discrepancy*	*Number of observations*	*Mean discrepancy*
Germany	6	0.656***	5	0.272

Notes: a. Romanian trade flows in the EFI Database are mainly for the 1990s.
b. Sample includes only trade flows with reported imports and exports both ≥ 100 m^3.
c. ***, **, *: mean is significantly different from zero at 1%, 5%, 10% level.

3.3 Romanian discrepancies compared to those for other European countries

Table 5 shows the mean discrepancies for exports of sawnwood by all European countries with at least 25 observations in the EFI Database. It includes the mean values for Romania from Table 1. In addition to the significance levels for tests of equality to zero, the table shows the significance levels for pairwise tests of the equality of each country's mean to the mean for Romania.[9] Results from these tests are indicated by daggers (†).

Unlike in Romania, the mean discrepancies for exports of NC sawnwood were significantly different from zero in many of the other European countries. In these cases, the mean discrepancies were mostly negative: imports reported by trading partners were less than European countries' reported exports. With the exception of Latvia, western European countries accounted for the largest discrepancies: Belgium-Luxembourg, Italy, Netherlands, Portugal, and Spain. Imports reported by the trading partners of these countries were, on average, only about two-thirds of the countries' reported exports. The mean discrepancies for these countries and several others were significantly different from the mean discrepancy for Romania.

Like Romania, many other European countries had discrepancies for exports of C sawnwood that were negative and statistically significant. Among these countries, only Slovenia had a mean discrepancy that was significantly larger than Romania's.

[9] Variances were allowed to differ between countries in these tests.

Table 5. Relative discrepancies (Δ_{ij}) for sawnwood exported by European countries during 1982-97, aggregated across all importing countries. Positive discrepancies indicate that reported imports were greater than reported exports; negative discrepancies indicate the reverse.

Country	*NC sawnwood*		*C sawnwood*	
	Number of observations	*Mean discrepancy*	*Number of observations*	*Mean discrepancy*
Austria	250	0.020	335	-0.079^{***}
Belgium-Lux.	320	$-0.155^{***,\dagger\dagger\dagger}$	153	-0.118^{***}
Croatia	90	-0.048^{*}	-	-
Czech Republic	64	–0.025	106	$-0.022^{\dagger\dagger}$
Denmark	268	-0.095^{***}	232	-0.114^{***}
Estonia	-	-	52	$0.006^{\dagger\dagger}$
Finland	154	$-0.085^{**,\dagger\dagger}$	464	-0.082^{***}
France	501	-0.039^{**}	293	$-0.031^{\dagger\dagger}$
Germany	446	0.020	312	$-0.029^{\dagger\dagger}$
Greece	84	-0.083^{*}	-	-
Hungary	48	0.039	26	$0.081^{\dagger}$
Ireland	-	-	28	-0.128^{**}
Italy	417	$-0.220^{***,\dagger\dagger\dagger}$	306	-0.072^{**}
Latvia	56	$-0.228^{***,\dagger\dagger\dagger}$	89	-0.177^{***}
Lithuania	46	0.003	59	-0.147^{***}
Netherlands	324	$-0.214^{***,\dagger\dagger\dagger}$	191	$-0.016^{\dagger\dagger}$
Norway	70	0.035	254	-0.116^{***}
Poland	197	$0.052^{***,\dagger\dagger}$	204	$0.008^{\dagger\dagger\dagger}$
Portugal	109	$-0.189^{***,\dagger\dagger\dagger}$	191	-0.109^{***}
Romania	***129***	***–0.034***	***124***	$\boldsymbol{-0.119^{***}}$
Russia	60	–0.077	80	-0.122^{***}
Slovakia	59	–0.031	54	-0.113^{***}
Slovenia	48	$0.101^{**,\dagger\dagger}$	42	$-0.251^{***,\dagger\dagger}$
Spain	193	$-0.183^{***,\dagger\dagger\dagger}$	173	-0.094^{***}
Sweden	198	$0.120^{***,\dagger\dagger\dagger}$	515	-0.086^{***}
Switzerland	118	0.000	92	$0.007^{\dagger\dagger\dagger}$
United Kingdom	256	$-0.123^{***,\dagger\dagger}$	180	-0.121^{***}
Yugoslavia	187	-0.072^{***}	98	$-0.029^{\dagger}$

Notes: a. Table includes only countries with at least 25 observations in the EFI Database.
b. Trade flows for Central and Eastern European countries in the EFI Database are mainly for the 1990s.
c. Sample includes only trade flows with reported imports and exports both ≥ 100 m^3.
d. ***, **, *: mean is significantly different from zero at 1%, 5%, 10% level.
e. †††, ††, †: mean is significantly different from Romanian mean at 1%, 5%, 10% level.

In a few cases, the discrepancies for NC and C sawnwood had opposite signs. This suggests that observed discrepancies might be due to intentional or unintentional misclassification of the products. We explore this possibility in the econometric analysis.

Table 6 shows the mean discrepancies for European countries' imports of sawnwood. Two differences from the results for exports may be noted for both NC and C sawnwood: somewhat fewer of the discrepancies are significantly different from zero, especially for C sawnwood, and most of these discrepancies are positive rather than negative. European countries tend to report imports that exceed their trading countries' reported exports. For NC sawnwood, no country has a statistically larger discrepancy than Romania's. For C sawnwood, the very small number of observations for Romania, just 11, is the likely cause of the lack of significant results for the pairwise means tests for any country.

To sum up, Romania's discrepancies are large by European standards in the cases of exports of C sawnwood (a negative discrepancy: imports reported by trading partners are less than exports reported by Romania) and imports of NC sawnwood (a positive discrepancy: imports reported by Romania are greater than exports reported by trading partners). We turn now to a consideration of factors that might explain these mean tendencies. We take a quick look at some basic theory before delving into detail on the econometric analysis.

Table 6. Relative discrepancies (Δ_{ij}) for sawnwood imported by European countries during 1982-97, aggregated across all exporting countries. Positive discrepancies indicate that reported imports were greater than reported exports; negative discrepancies indicate the reverse.

Country	*NC sawnwood*		*C sawnwood*	
	Number of observations	*Mean discrepancy*	*Number of observations*	*Mean discrepancy*
Austria	268	0.171^{***}	229	0.054^{**}
Belgium-Lux.	404	$0.008^{\dagger\dagger}$	297	0.006
Croatia	44	$0.029^{\dagger}$	51	–0.036
Cyprus	150	0.193^{***}	110	0.132^{***}
Czech Republic	46	0.179^{***}	46	0.014
Denmark	311	$-0.009^{\dagger\dagger}$	204	0.028
Faeroe Islands	-	-	45	-0.124^{**}
Finland	255	$0.021^{\dagger\dagger}$	72	–0.026
France	439	0.082^{***}	315	–0.022
Germany	486	$0.005^{\dagger\dagger}$	334	0.075^{***}
Greece	216	$-0.019^{\dagger}$	164	0.061
Hungary	39	0.113^{*}	59	0.209^{***}
Iceland	89	$-0.019^{\dagger\dagger}$	141	0.017
Ireland	216	$0.017^{\dagger\dagger}$	190	–0.009
Italy	547	0.168^{***}	356	0.117^{***}
Malta	63	0.097	64	0.359^{***}
Netherlands	456	$0.023^{\dagger\dagger}$	310	0.025
Norway	286	0.184^{***}	160	0.084^{***}
Poland	71	0.154^{**}	64	0.047
Portugal	193	0.113^{***}	117	0.032
Romania	***32***	***0.199*****	***11***	***–0.090***
Russia	48	0.201^{***}	32	0.090
Slovenia	64	0.059	50	-0.172^{**}
Spain	436	0.107^{***}	268	0.084^{***}
Sweden	338	$0.039^{*,\dagger\dagger}$	152	-0.066^{*}
Switzerland	239	0.101^{***}	236	0.000
United Kingdom	510	0.070^{***}	384	0.089^{***}
Yugoslavia	31	0.071	29	–0.118

Notes: a. Table includes only countries with at least 25 observations in the EFI Database (except for Romania).
b. Trade flows for Central and Eastern European countries in the EFI Database are mainly for the 1990s.
c. Sample includes only trade flows with reported imports and exports both ≥ 100 m^3.
d. ***, **, *: mean is significantly different from zero at 1%, 5%, 10% level.
e. †††, ††, †: mean is significantly different from Romanian mean at 1%, 5%, 10% level.

4 A theoretical model of trade statistics discrepancies

4.1 Components of trade statistics discrepancies

In this section we describe the theoretical model that guided our econometric analysis. Define the following variables related to country *i*'s imports from country *j*:

- I^{A}_{ij} Actual imports: the true amount imported
- I^{R}_{ij} Reported imports: the amount published in a country's annual trade statistics
- I^{UR}_{ij} Unreported imports: the amount that is unreported due to illegal activities like smuggling and underinvoicing
- I^{M}_{ij} Measurement error: errors in measuring or recording imports.

The following identity holds:

$$I^{R}_{ij} = I^{A}_{ij} + I^{M}_{ij} - I^{UR}_{ij} \tag{3}$$

This says that reported imports (I^{R}_{ij}) can differ from actual imports (I^{A}_{ij}) for two reasons, measurement error (I^{M}_{ij}) and unreporting (I^{UR}_{ij}). Note that we define the latter as an intentional, illegal act. I^{M}_{ij} can have any sign: measurement error can result in reported imports being understated or overstated. The other variables are always nonnegative.

The corresponding variables for country *j*'s reported exports to country *i* are

- E^{A}_{ij} Actual exports
- E^{R}_{ij} Reported exports
- E^{UR}_{ij} Unreported exports
- E^{M}_{ij} Errors in measuring exports (including recording errors)

Like unreported imports, unreported exports refer to quantities affected by illegal trade practices. The identity for exports is

$$E^{R}_{ij} = E^{A}_{ij} + E^{M}_{ij} - E^{UR}_{ij}\,. \tag{4}$$

Taking the difference between the two identities, we obtain:

$$I^{R}_{ij} - E^{R}_{ij} = (I^{A}_{ij} - E^{A}_{ij}) + (I^{M}_{ij} - E^{M}_{ij}) - (I^{UR}_{ij} - E^{UR}_{ij}). \tag{5}$$

This expression indicates that an observed discrepancy between reported imports and reported exports can be disaggregated into three components: a discrepancy in the actual trade flow ($I^{A}_{ij} - E^{A}_{ij}$), a discrepancy due to measurement error ($I^{M}_{ij} - E^{M}_{ij}$), and a discrepancy due to unreported imports or exports ($I^{UR}_{ij} - E^{UR}_{ij}$).

4.2 Factors affecting the components

Consider first the discrepancy in the actual trade flow. Actual imports can differ from actual exports only if a shipment does not arrive (e.g., a ship is redirected during its voyage or its cargo is lost at sea) or if transport time causes a shipment to arrive in the importing country in the next calendar year. If a shipment does not arrive at all, then there is a one-time, negative discrepancy in the year the product was exported: reported imports are less than reported exports. If the shipment arrives but not until the next calendar year, then there is a negative discrepancy in the year the product was exported and a positive discrepancy the following year when the product is imported.

Regarding the second component of the discrepancy, measurement error, we have already mentioned two factors that tend to reduce its impact on the data we analyzed: the data cleaning process by EFI staff, and the exclusion of reported trade flows of less than 100 m^3. But we do not expect these factors to completely eliminate measurement error. In section 5.1, we explain how we used the raw and cleaned data from EFI to develop a measure of potential measurement error. We also explain how we investigated misclassification of the species group of sawnwood (i.e., whether it is NC or C), which could reflect either measurement error or an intentional act by importers or exporters.

Finally, consider the third component, discrepancies due to unreported imports or exports. Isolating this component is the principal objective of our econometric analysis. Appendix 7 contains a technical description of our model of this component. We sketch only the main features here. The model is premised on the assumption that companies underreport the amount they import or export, whether by falsifying customs forms or by circumventing customs authorities altogether, when doing so enables them to evade some costly government regulation. Import tariffs, export taxes, and nontariff barriers are obvious examples. Companies that engage in illegal logging practices, such as harvesting prohibited species or exceeding annual allowable cuts, might also underreport exports to avoid detection.

Companies face a probability of being caught if they underreport the amount traded, and if they are caught they suffer a penalty (e.g., a fine). The probability of being caught is assumed to be higher if: (i) they underreport a greater amount, and (ii) the country they are exporting from or importing to has a higher quality of governance. Companies select the amount of underreporting that balances the expected reduction in regulatory costs (e.g., payments of import or export duties) if they are not caught against the penalty they must pay if they are caught. Assuming that duties are a principal regulation that companies seek to evade, the model implies that the discrepancy due to unreported imports and exports is a function of import and export prices, import and export duties, fines on unreported imports and exports, and quality of governance in exporting and importing countries.

4.3 Implications for observed discrepancies in Romania

According to this model of intentional underreporting, a negative discrepancy implies that illegal activities are greater in the importing country (imports are underreported more than exports, hence the discrepancy is negative), while a positive discrepancy implies the opposite (exports are underreported more than imports, hence the discrepancy is positive). Recall from Tables 1 and 3 that the significant mean discrepancies for Romania were for a negative one for exports of C sawnwood and a positive one for imports of NC sawnwood. These signs imply that the discrepancies are more likely due to illegal activities in Romania's trading partners than in Romania itself. But to be confident that this implication is true, we must take into account the possible effects of the other two components. That is the purpose of the econometric analysis, to which we now turn.

5 Econometric analysis

The econometric analysis attempts to disentangle and determine the relative importance of the three components of observed discrepancies between imports and exports. The idea is to isolate the third component, intentional unreporting, by controlling for the first two, actual discrepancies and measurement error. In the first part of this section we describe the explanatory variables that we included in the econometric analysis to capture key aspects of the theoretical model. We present results of the econometric analysis in the second part of the section.

5.1 Specification of model and definitions of variables

The econometric model included variables intended to capture the effects of all three components of the discrepancy between reported imports and exports. An observation (a data point) in this model is defined as an annual bilateral trade flow in a given direction between a pair of countries. For example, reported imports and exports for sawnwood shipped from Romania to Germany in 1995 is a different observation from reported imports and exports for sawnwood shipped from Germany to Romania in the same year. The full specification of the econometric model was:

$$\begin{aligned}\Delta_{ijt} = {} & \beta_0 \\ & + \beta_1\mathrm{IM\_ADJUST\_POS}_{ijt} + \beta_2\mathrm{IM\_ADJUST\_NEG}_{ijt} \\ & + \beta_3\mathrm{EX\_ADJUST\_POS}_{ijt} + \beta_4\mathrm{EX\_ADJUST\_NEG}_{ijt} \\ & + \beta_5\mathrm{CONTIGUOUS}_{ijt} + \beta_6\mathrm{SWITCH\_SIGN}_{ijt} \\ & + \beta_7\mathrm{IM\_DUTY}_{it} + \beta_8\mathrm{IM\_UVAL}_{ijt} + \beta_9(\mathrm{IM\_DUTY}\times\mathrm{UVAL})_{ijt} + \beta_{10}\mathrm{EX\_UVAL}_{ijt} \\ & + \beta_{11}\mathrm{IM\_GOV}_{it} + \beta_{12}(\mathrm{IM\_DUTY}\times\mathrm{GOV})_{ijt} + \beta_{13}\mathrm{EX\_GOV}_{jt} \\ & + \varepsilon_{ijt} \qquad (6)\end{aligned}$$

t represents the year of an observation, the β's are estimated coefficients on the explanatory variables, and ε_{ijt} is the error term. To simplify notation in the descriptions of the variables that follow below, we suppress the time subscript t except in cases where it plays a role in defining the variables.

5.1.1 Dependent variable: Δ_{ij}

We used the cleaned data series for imports and exports in the EFI Database, i.e. the series QUANTITY, to construct $I^R_{ij} - E^R_{ij}$. As described in section 2.2, we expressed it in relative terms:

$$\Delta_{ij} \equiv \frac{I^R_{ij} - E^R_{ij}}{I^R_{ij} + E^R_{ij}}.$$

One reason for dividing by $I^R_{ij} + E^R_{ij}$ was to reduce the potential for heteroskedasticity. In the regression results, Δ_{ij} is named DELTA.

5.1.2 Explanatory variables related to measurement error: IM_ADJUST, EX_ADJUST

We used information in the EFI Database to construct variables that reflect *potential* measurement errors in reported imports and exports. Recall that the database includes the original COMTRADE data, the series QORIG, in addition to the cleaned series QUANTITY. Since I^R_{ij} and E^R_{ij} denote the cleaned data, denote the original, "dirty" data by

I^{RO}_{ij} Reported imports according to COMTRADE
E^{RO}_{ij} Reported exports according to COMTRADE.

The following variables express, in relative terms, the adjustments made by EFI:

$$\text{IM\_ADJUST} = \frac{I^R_{ij} - I^{RO}_{ij}}{I^R_{ij} + I^{RO}_{ij}}$$

$$\text{EX\_ADJUST} = \frac{I^R_{ij} - I^{RO}_{ij}}{I^R_{ij} + I^{RO}_{ij}}.$$

As with Δ_{ij}, the value of these variables ranges from –1 to +1. IM_ADJUST is negative if EFI adjusted the COMTRADE quantity downward, with an extreme value of –1 of EFI reduced it all the way to zero. It is positive if EFI adjusted the COMTRADE quantity upward, with an extreme value of +1 if the QORIG series included no imports by country *i* from country *j* but EFI had evidence to the contrary. It is zero if EFI made no correction. EX_ADJUST is interpreted the same way.

We hypothesized that data points with large adjustments were ones where measurement error was more likely to persist even after EFI's corrections. That is, we interpreted a larger value of IM_ADJUST (or EX_ADJUST) as an indicator of greater uncertainty about the quantity imported (or exported). We have no information on whether the residual error is positive or negative. That is, we have no way of knowing whether EFI's adjustments were too large or too small. For this reason, we included positive and negative values of IM_ADJUST and EX_ADJUST as separate variables:

IM_ADJUST_POS = IM_ADJUST if IM_ADJUST > 0
= 0 otherwise

IM_ADJUST_NEG = IM_ADJUST if IM_ADJUST < 0
= 0 otherwise

EX_ADJUST_POS = EX_ADJUST if EX_ADJUST > 0
= 0 otherwise

EX_ADJUST_NEG = EX_ADJUST if EX_ADJUST < 0
= 0 otherwise.

For the same reason, we have no expectation about the signs of the coefficients on these variables.

One specific form that measurement error could take is the misrecording of the species group of the sawnwood: recording NC sawnwood as C sawnwood, or vice versa. We investigated this possibility by adding to Equation (6) the observed discrepancy for C sawnwood, DELTA_C, in the case of the regression model for NC sawnwood, and the observed discrepancy for NC sawnwood, DELTA_NC, in the case of the regression model for C sawnwood. We expect the coefficients on these variables to be negative: misrecording causes the two species groups to have discrepancies of opposite signs. The interpretation of the coefficients on these variables is complicated, however, by the fact that companies might be expected to intentionally misstate the species group if trade regulations differ for the two species groups. For example, if the import tariff on NC sawnwood is greater than the import tariff on C sawnwood, then companies might misrepresent shipments of NC sawnwood as C sawnwood in order to receive the more favorable tariff rate. The expected coefficient on the variable would still be negative, but the reason would differ.

5.1.3 Explanatory variables related to discrepancies in actual flows: CONTIGUOUS, SWITCH_SIGN

We expect that shipments are more likely to arrive and shipping times are shorter when countries share a border, because shipping might then be by land (truck or rail) instead of by sea. We therefore included a dummy variable, CONTIGUOUS, which has a value of 1 when trading partners share a border and 0 otherwise. If this variable reflects mainly the greater likelihood that shipments arrive at their original destination, then we expect the coefficient on it to be positive: imports are more likely to be as large as exports when countries share a border. That is, a negative discrepancy, which indicates that reported imports are less reported exports, is less likely to be observed. If instead the variable reflects mainly shorter shipping times, then the coefficient on it could be either negative or positive, depending on whether the excess of exports over imports in the shipping year (smaller for countries that share a border; hence, a positive coefficient) weighs more heavily in the statistics than the excess of imports over exports in the receiving year (also smaller for countries that share a border; a negative coefficient). Given that discrepancies due purely to shipping delays should wash out over time, we expect the magnitude of the coefficient to be small, regardless of whether it is positive or negative.

To test more directly for the presence of shipment lags, we also included a variable, SWITCH_SIGN, that equaled the lagged discrepancy Δ_{ijt-1} when a positive discrepancy (imports exceed exports) was preceded by a negative discrepancy (imports exceed exports)—i.e., when $\Delta_{ijt} > 0$ and $\Delta_{ijt-1} < 0$—and 0 otherwise. We expect the coefficient on this variable to be negative, with an absolute value less than one: the coefficient shows the proportion of the negative discrepancy that arrives in the following year.

5.1.4 Explanatory variables related to unreported flows: IM_DUTY$_{it}$, IM_UVAL$_{ijt}$, EX_UVAL$_{ijt}$, IM_GOV$_{it}$, EX_GOV$_{jt}$

We were able to compile cross-country data for all the variables in the theoretical model except the level of fines and other punishments that companies faced if they were caught underreporting imports or exports. IM_DUTY is the sawnwood import tariff. We pieced together data for this variable from tariff schedules in various GATT and WTO documents. We did not include a corresponding variable for export taxes, because such taxes equaled zero in every country for which we had data. We expect the coefficient on this variable to be negative: higher tariffs create an incentive for greater underreporting of imports—hence, larger negative discrepancies as we have defined them, imports minus exports.

IM_UVAL and EX_UVAL, the import and export unit values, are our proxies for sawnwood import and export prices. We constructed them by dividing reported import and export values by the corresponding quantities (the QUANTITY series). We expressed them in constant (inflation-adjusted) US dollars per cubic meter. One reason we limited the sample to reported flows of 100 cubic meters was to reduce the error in constructing these variables. For example, if a country imports or exports only 1-9 cubic meters in a year (and there were some such observations in the EFI database), then we can only have confidence in our estimate of the unit value to an order of magnitude (i.e., 10 times). To the extent that the regulations companies seek to evade are more costly for sawnwood that is more valuable, which would be true not only for ad valorem import tariffs but also nontariff trade barriers like export quotas, we expect the coefficient on IM_UVAL to be negative (higher import prices create an incentive for greater underreporting of imports, hence a more negative discrepancy) and the coefficient on EX_UVAL to be positive (higher export prices create an incentive for greater underreporting of exports, hence a more positive discrepancy).

IM_GOV and EX_GOV are the indicators of quality of governance for importing and exporting countries, respectively. We constructed these variables using economywide indicators of institutional quality developed by Political Risk Services (PRS). PRS rates countries according to 24 measures of economic, social, and political risks in its monthly *International Country Risk Guide*. Knack and Keefer (1995) selected five of these measures and compiled annual time series for a large set of countries. The three most relevant to the risk of illegal trade activities are:[10]

[10] The other two variables are expropriation risk (the risk of confiscation and nationalization) and government repudiation of contracts (an indicator of contract enforcement between the government and private parties).

1. Corruption ("the degree of corruption among government officials")

2. Rule of law ("law and order tradition"; "the soundness of the established institutions to implement laws and settle claims")

3. Bureaucratic quality ("efficiency in the provision of government services and the independence of the civil service from political pressures").

The ratings for these variables range from 0 to 10, with larger values indicating better governance (i.e., less corruption, stronger rule of law, more efficient and independent bureaucracy). We initially included these variables separately in the regression models, but the coefficients on them tended not to be statistically significant because the variables are relatively highly correlated within a country (i.e., the problem of multicollinearity). Significance levels and adjusted goodness-of-fit statistics improved when we instead included aggregate governance variables constructed by summing the three variables and dividing by 3.[11] IM_GOV and EX_GOV are these aggregate measures. We expect the coefficients on these variables to be positive and negative, respectively: stronger governance in the importing country makes discrepancies less likely to be negative, because there is less evasion of import regulations, while stronger governance in the exporting country makes discrepancies less likely to be positive, because there is less evasion of export regulations.

The IM_DUTY×UVAL and IM_DUTY×GOV variables in Equation (6) are interaction terms constructed by multiplying IM_DUTY by IM_UVAL and IM_DUTY by IM_GOV. These interactions are implied by our theoretical model; see Appendix 7. We expect the sign of the former to be negative: the incentive to underreport imports is especially strong when both the import price and the import tariff are high. We have no expectation for the sign of the latter, because IM_DUTY and IM_GOV have opposing effects on the incentive to underreport imports.

5.2 Estimation procedures

We estimated Equation (6) in sequential fashion, beginning with a simple version that included only the measurement-error variables and then adding in the other explanatory variables. For both NC and C sawnwood, we found that the signs, magnitudes, and significance levels of the coefficients changed relatively little as we increased the list of explanatory variables. This provides some confidence in the robustness of the coefficient estimates.

We estimated the model initially using ordinary least squares (OLS). Results of Cook-Weisberg tests indicated, however, that heteroskedasticity was present: the variance of the error term differed across the bilateral flows. This could lead to two statistical problems, biased estimates of the standard errors of the coefficients and inefficient (imprecise) estimates of the coefficients. In response to the former problem, we reestimated the standard errors of the coefficients using White's method. We found that they differed little from the OLS estimates.

[11] Other cross-country studies have used combined versions of the Knack and Keefer variables for similar reasons. Using the first principal component of the three IRIS variables instead of the simple average did not change the econometric results significantly.

One cause of heteroskedasticity in OLS models can be a violation of the assumption that the mean of the error term is identical and equal to zero across all observations in the sample. We investigated this possibility by estimating a generalized least squares (GLS) model with random effects. The means of the error terms in this model were allowed to differ across bilateral flows:

$$\varepsilon_{ijt} = \mu_{ij} + \eta_{ijt}.$$

μ_{ij} is the random effect for imports by country *i* from country *j*—the mean of the error term for that particular bilateral flow—and η_{ijt} is an error term that satisfies the standard OLS assumptions of being independently and identically distributed with a mean of zero. We used a Breusch-Pagan Lagrangian multiplier test to determine whether the random effects were statistically significant. We found that they were.

Coefficient estimates from the random effects model are unbiased and more efficient than OLS estimates as long as the random effects are not correlated with the other explanatory variables in the model. If the random effects are correlated with the other explanatory variables, however, then the coefficient estimates are biased, which is a more serious problem than inefficiency. Results of a Hausman test indicated that these correlations were indeed statistically significant, so we rejected the random effects estimates.

An alternative model that generates unbiased, though inefficient, coefficient estimates is a GLS model that includes fixed effects instead of random effects. We estimated this model by allowing the intercept in the Equation (6), β_0, to differ across the bilateral flows (i.e., β_{0ij}). We used an *F* test to determine whether the fixed effects were jointly different from zero. We found that they were.

Our preferred econometric results are therefore the ones from the GLS model with fixed effects. We show these results in Table 7. Appendix 8 contains results for the other, intermediate models.

5.3 Results

The sample in the econometric analysis included all bilateral trade flows in the EFI Database during 1982-97 that satisfied two conditions: (i) either the importer or the exporter was a European country, and (ii) reported imports and reported exports were each at least 100 cubic meters. The sample period, 1982-97, was determined primarily by the availability of the Knack and Keefer governance variables. As Table 7 indicates, there are more observations in the sample for NC sawnwood: 6,140 trade flows between 1,058 pairs of countries,[12] vs. 4,786 trade flows between 781 pairs of countries for C sawnwood.

The results provide evidence that all three hypothesized components of discrepancies in reported trade statistics—measurement error, discrepancies in actual trade flows, and intentional underreporting—play a role in explaining the discrepancies in the sample. One of the four measurement error variables is significantly different from zero at a 5-percent level or better for

[12] Direction of trade affects the definition of a pair of trading countries. For example, the fixed effect for Romanian exports to Germany is different from the fixed effect for German exports to Romania.

both products: EX_ADJUST_POS for NC sawnwood and IM_ADJUST_NEG for C sawnwood. Discrepancies were significantly larger for bilateral flows where EFI made these adjustments to the original volume data in QORIG.

In results that are shown in Appendix 8 but not here, we also found that our variables for the misrecording of species group, C_DELTA and NC_DELTA, had statistically significant coefficients when we added them to the regression models for NC and C sawnwood, respectively. To our surprise, the coefficients were positive instead of negative. The magnitudes of the coefficients were small, however, and the addition of these variables had a negligible impact on the signs, magnitudes, and statistical significance of the coefficients on the other explanatory variables. For this reason, we conclude that misclassification of species group, whether unintentional or otherwise, is not an important explanation for observed discrepancies between import and export statistics.

Because the fixed effects are defined for pairs of countries, the CONTIGUITY variable drops out of the model. The coefficient on the remaining variable related to discrepancies in actual trade flows, SWITCH_SIGN, is highly significant, negative, and not statistically different for the two products. As expected, its absolute magnitude is less than 1: 60-70 percent of a negative discrepancy (reported exports exceeding reported imports) shows up as a positive discrepancy in the following year. This suggests that shipment lags play a role in explaining negative discrepancies.

The remaining variables pertain to the intentional unreporting of imports and exports. Results for the two products are similar for several of the variables. In particular, and as expected, the coefficients on IM_UVAL and EX_UVAL are negative and positive, respectively. Both are highly statistically significant, and their magnitudes are comparable for the two products. Also as expected, the coefficient on IM_DUTY×UVAL is negative for both products, though it is significant at the 5-percent level only for C sawnwood. The coefficient on the other interaction term, IM_DUTY×GOV, has a positive sign for both products, but it too is significant only for C sawnwood.

Results for the other variables match our expectations less well. The coefficient on IM-DUTY is significant for both products but negative only for C sawnwood. The coefficient on EX_GOV is significant for both products but has the wrong sign, positive, for both. The coefficient on IM_GOV is not significant for either product and is incorrectly signed for NC sawnwood.

Regarding the coefficient estimates, the results are therefore stronger for C sawnwood than for NC sawnwood. The best results among the variables related to unreported imports and exports are for the sawnwood price variables, IM_UVAL and EX_UVAL. One sense in which the results are stronger for NC sawnwood than for C sawnwood, however, is in terms of goodness-of-fit. The R^2 statistic is twice as large for NC sawnwood as for C sawnwood. Even the former is very small, however: the value of 0.131 indicates that the regression model explains only 13.1 percent of the variation in the discrepancies within and between pairs of trading countries. Most of the variation remains unexplained and in the error term, η_{ijt}. Despite this low explanatory power, the large F statistics—118.28 for NC, 68.26 for C—indicate that the overall regression models for the two products are statistically significant.

Table 7. Econometric results (GLS, fixed effects): full model, 1982-97

a. Nonconiferous sawnwood

```
Fixed-effects (within) regression               Number of obs      =      6140
Group variable (i): IDnum                       Number of groups   =      1058

R-sq:  within  = 0.2187                         Obs per group: min =         1
       between = 0.0680                                        avg =       5.8
       overall = 0.1313                                        max =        16

                                                F(12,5070)         =    118.28
corr(u_i, Xb)  = -0.0669                        Prob > F           =    0.0000

------------------------------------------------------------------------------
       DELTA |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
IM_ADJUST_POS |   .0448595   .0251938     1.78   0.075    -.0045312    .0942502
IM_ADJUST_NEG |  -.0319346   .0497407    -0.64   0.521     -.129448    .0655787
EX_ADJUST_POS |  -.0887022   .0201782    -4.40   0.000    -.1282603   -.0491441
EX_ADJUST_NEG |  -.0688735   .0615913    -1.12   0.264    -.1896191    .0518721
   CONTIGUOUS |  (dropped)
  SWITCH_SIGN |  -.6393081   .0359603   -17.78   0.000    -.7098058   -.5688105
      IM_DUTY |   .4784925   .2249414     2.13   0.033     .0375103    .9194748
      IM_UVAL |  -.0003423   .0000163   -20.94   0.000    -.0003743   -.0003102
 IM_DUTYxUVAL |  -.0018925   .0013228    -1.43   0.153    -.0044857    .0007007
      EX_UVAL |   .0003838   .0000175    21.97   0.000     .0003496    .0004181
       IM_GOV |   -.010431   .0108713    -0.96   0.337    -.0317434    .0108813
  IM_DUTYxGOV |   .0004289   .0002527     1.70   0.090    -.0000665    .0009243
       EX_GOV |   .0241524   .0092668     2.61   0.009     .0059854    .0423194
        _cons |  -.0577721    .068527    -0.84   0.399    -.1921146    .0765704
-------------+----------------------------------------------------------------
      sigma_u |  .30855177
      sigma_e |  .24280513
          rho |  .61757335   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(1057, 5070) =     6.18          Prob > F = 0.0000
```

b. Coniferous sawnwood

```
Fixed-effects (within) regression               Number of obs      =      4786
Group variable (i): IDnum                       Number of groups   =       781

R-sq:  within  = 0.1702                         Obs per group: min =         1
       between = 0.0303                                        avg =       6.1
       overall = 0.0645                                        max =        16

                                                F(12,3993)         =     68.26
corr(u_i, Xb)  = -0.1858                        Prob > F           =    0.0000

------------------------------------------------------------------------------
       DELTA |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
IM_ADJUST_POS |  -.0232659   .0339507    -0.69   0.493    -.0898282    .0432965
IM_ADJUST_NEG |   .1583233   .0701285     2.26   0.024     .0208323    .2958142
EX_ADJUST_POS |  -.0139032   .0285868    -0.49   0.627    -.0699494    .0421429
EX_ADJUST_NEG |  -.0948278   .1115058    -0.85   0.395    -.3134414    .1237858
   CONTIGUOUS |  (dropped)
  SWITCH_SIGN |  -.6532216   .0378401   -17.26   0.000    -.7274094   -.5790339
      IM_DUTY |   -1.13924   .3429656    -3.32   0.001    -1.811644   -.4668363
      IM_UVAL |  -.0006881   .0000413   -16.67   0.000    -.0007691   -.0006072
 IM_DUTYxUVAL |  -.0112559   .0042262    -2.66   0.008    -.0195415   -.0029702
      EX_UVAL |   .0006286    .000037    16.98   0.000      .000556    .0007011
       IM_GOV |   .0123333   .0108648     1.14   0.256    -.0089679    .0336344
  IM_DUTYxGOV |   .0028616   .0008209     3.49   0.000     .0012522    .0044711
       EX_GOV |   .0495795   .0141925     3.49   0.000     .0217544    .0774047
        _cons |  -.2984837   .0881321    -3.39   0.001    -.4712719   -.1256955
-------------+----------------------------------------------------------------
      sigma_u |  .31865754
      sigma_e |   .2448774
          rho |  .62871747   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(780, 3993) =     5.83           Prob > F = 0.0000
```

5.4 Estimating the impact of unreported trade on observed discrepancies

It is mechanically possible to use the regression results to estimate the portion of discrepancies for Romania or any other country that was due to unreported trade. One could do this by constructing the following partial fitted value:

$$\begin{aligned} \text{UNREPORTED}_{ijt} = \; & \hat{\beta}_7 \,\text{IM\_DUTY}_{it} + \hat{\beta}_8 \,\text{IM\_UVAL}_{ijt} + \hat{\beta}_9 \,(\text{IM\_DUTY}\times\text{UVAL})_{ijt} + \hat{\beta}_{10} \,\text{EX\_UVAL}_{ijt} \\ & + \hat{\beta}_{11} \,\text{IM\_GOV}_{it} + \hat{\beta}_{12} \,(\text{IM\_DUTY}\times\text{GOV})_{ijt} + \hat{\beta}_{13} \,\text{EX\_GOV}_{jt} \,. \end{aligned} \tag{7}$$

$\hat{\beta}_7$, $\hat{\beta}_8$, etc. are the estimated coefficients from Table 7. Note that this equation includes only the variables that are related to unreported trade: import and export prices, import duties, and quality of governance. If we inserted values for, say, Romanian exports of NC sawnwood and countries that import that product from Romania, then we could in principle predict the portion of the discrepancy that results from unreported trade.

In view of the poor fit of the regression equations in Table 7 and the problems with the signs and significance levels of some of the estimated coefficients, including some key ones related to unreported trade, we decided that this calculation is too unreliable to perform.

6 Conclusions

This report has attempted to answer two questions. First, how large are statistical discrepancies between reported imports and exports for bilateral flows of sawnwood traded by European countries, Romania in particular? We focus on discrepancies in physical (volume) terms, i.e. cubic meters. Second, do these discrepancies reflect illegal activities, such as intentional underreporting of the amounts imported or exported to evade tariff and nontariff barriers or to conceal timber that was harvested illegally?

Regarding the first question, we found that the mean discrepancies between trade volumes reported by European countries and the volumes reported by their trading partners were significantly different from zero for many European countries during 1982-97. This was true for European countries both as importers and as exporters, and for both nonconiferous and coniferous sawnwood. Romania's discrepancies were large by European standards in two cases: Romanian exports of coniferous sawnwood, where imports reported by trading partners were on average 20 percent less than exports reported by Romania; and Romanian imports of nonconiferous sawnwood, where imports reported by Romania were on average half again as large as exports reported by trading partners. In the former case, only Slovenia had a mean discrepancy that was significantly larger than Romania's. No other European country had a discrepancy larger than Romania's in the latter case. Romania's discrepancies were especially large for exports of coniferous sawnwood to Saudi Arabia and imports of nonconiferous sawnwood from Germany. Discrepancies were also significant for exports of nonconiferous sawnwood to Sweden and the United Kingdom; imports reported by these two trading partners were smaller than the exports reported by Romania.

To answer the second question, we analyzed data on bilateral trade statistics discrepancies pooled across European countries. Our analysis was guided by a theoretical model that distinguished three potential, and not mutually exclusive, causes of discrepancies in reported trade flows: measurement error, discrepancies in actual flows (e.g., shipments leave an exporting country in one year but do not arrive in the importing country until the following year), and intentional underreporting of imports or exports to evade government regulations. We found statistical support for each of these causes, including intentional underreporting. But even in combination, the three causes explained very little of the variation in the discrepancies across countries and over time. Discrepancies between European countries' trade statistics and those of their trading partners are evidently mostly due to factors not explained by the econometric model. Moreover, some of the variables that we included in the econometric model to represent these factors had impacts opposite of what theory predicts.

One of the purposes of this study was to evaluate the practical usefulness of econometric methods for detecting illegal trade practices in the forest sector. For several reasons, our experience with the analysis presented in this report leaves us skeptical about the usefulness of such methods. The first is the simple fact that any econometric approach that is based on observed statistical discrepancies is necessarily blind to underreporting that occurs simultaneously at both the point of export and the point of import. An example is smuggling that is not detected by the customs authorities of either the exporting country or the importing country. Even when underreporting occurs more in one country than in the other, thus leading to an observable discrepancy, the explanatory variables in a model might not do a good job of completely capturing the factors that determine the degree of underreporting. Illegal activities could remain undetected in the portion of the variation in the discrepancies that the model fails to explain—which in our case was most of the variation. A third reason relates to the basis for measuring trade statistics discrepancies. We focused on discrepancies defined in terms of physical trade volumes, to avoid the obvious problems associated with discrepancies defined in terms of trade values (e.g., transport costs and exchange rate fluctuations). But it is possible that volumes could be reported accurately but values could be intentionally underreported. Our analysis misses this type of underreporting. Finally, and most generally, an econometric study that focuses on international trade has no bearing on illegal activities that occur purely in a domestic context, such as illegal felling of timber that is processed and consumed locally or collusion in timber auction markets. Such illegal activities could well be much more important than the ones in the trade sector that were the focus of the econometric analysis in this study.

Although improved data might overcome some of the shortcomings of econometric methods for detecting illegal trade activities in the forest sector, for an individual country like Romania we suspect that simpler statistical techniques like the ones used in section 3 of this report are more useful. Simple statistics like mean values that identify trading partners with whom Romania has persistent and large discrepancies could be used by customs authorities and NGOs as a guide for determining which shipments to check more carefully. Even this approach is not necessarily easy to implement, however, as it requires not just access to Romanian trade statistics, which should not be a problem for Romanian customs authorities, but also access to statistics from trading partners. International cooperation between custom authorities is thus required, especially if something close to real-time monitoring is desired. Although statistics on bilateral flows can be obtained from sources such as the EFI Database, they are published with a delay of several years. Moreover, they are based on product definitions that might be too aggregate for monitoring purposes. For example, to design an effective targeted inspection program, Romanian customs authorities might require the precision of knowing that the statistical discrepancy for sawnwood exported to a particular country pertains to, say, beech rather the broad category of nonconiferous sawnwood.

Literature cited

Durst, P, D. Ingram, and J. Laarman. 1986. “Inaccuracies in forest products trade statistics.” *Forest Products Journal* 36:9.

Feenstra, R.C. 2000. “World trade flows, 1980-97.” Center for International Data, University of California, Davis.

Feenstra, R.C., W. Hai, W.T. Woo, and S. Yao. 1999. “Discrepancies in international data: an application to China-Hong Kong entrepôt trade.” *American Economic Review* (May):338-343.

Feenstra, R.C., and G. Hanson. 2000. “Aggregation bias in the factor content of trade: evidence from U.S. manufacturing.” *American Economic Review* 90(2):155-160.

Fisman, R., and S.-J. Wei. 2001. “Tax rates and tax evasion: evidence from ‘missing imports’ in China.” *NBER Working Paper No. 8551*. NBER, Cambridge.

Johnson, S. 2002. “Documenting the undocumented.” *ITTO Tropical Forest Update* 12(1):6-9.

Knack, S., and P. Keefer. 1995. “Institutions and economic performance: cross-country tests using alternative institutional measures.” *Economics and Politics* 7(3):207-227.

Lichtenberg, R.M. 1959. “The role of middleman transactions in world trade.” *NBER Occasional Paper No. 64*. NBER, New York.

Pritchett, L. and Sethi. 1994. “Tariff rates, tariff revenue, and tariff reform: some new facts.” *World Bank Economic Review* 8(1):1-16.

Woolley, H.B. 1966. “Measuring transactions between world areas.” *Studies in International Economic Relations, No. 3*. NBER, New York.

APPENDICES

Appendix 1: Definitions of sawnwood in the EFI/WFSE Trade Flow Database

a. Nonconiferous (NC) sawnwood		
SITC Revision	*SITC Code*	*UN Code*
1	2111.0	2431
2	2121.0	2481
3	2131.0	2481
4	2141.0	440610
4	2142.0	440690
5	2151.0	440610
5	2152.0	440690
1	2311.0	2433
2	2321.0	2483
3	2331.0	2484
3	2332.0	2485
4	2341.0	440721
4	2342.0	440722
4	2343.0	440723
4	2344.0	440791
4	2345.0	440792
4	2346.0	440799
4	2347.0	440920
5	2350.0	440729
5	2353.0	440920
5	2354.0	440791
5	2355.0	440792
5	2356.0	440799
5	2357.0	440724
5	2358.0	440725
5	2359.0	440726

b. Coniferous (C) sawnwood		
SITC Revision	*SITC Code*	*UN Code*
1	2211.0	2432
2	2221.0	2482
3	2231.0	2482
3	2232.0	2483
4	2241.0	440710
4	2242.0	440910
5	2251.0	440710
5	2252.0	440910

Appendix 2: Importers of NC sawnwood from Romania in the EFI/WFSE Trade Flow Database

Algeria
Austria
Belgium-Luxembourg
Bulgaria
China
Cyprus
Czech Rep
Denmark
Egypt
Estonia
Finland
France
Germany
Germany FR
Greece
Hong Kong
Hungary
Israel
Italy
Jordan
Korea Rep
Malaysia
Malta
Moldova
Morocco
Netherlands
Norway
Pakistan
Russian Federation
Saudi Arabia
Singapore
Slovenia
South Africa
Spain
Sweden
Switzerland
Syria
Tunisia
Turkey
UK
USA
Ex-USSR
Yugoslavia

Appendix 3: Importers of C sawnwood from Romania in the EFI/WFSE Trade Flow Database

Algeria
Australia
Austria
Belgium-Luxembourg
Croatia
Cyprus
Czech Rep
Egypt
France
Germany
Germany FR
Greece
Hong Kong
Hungary
Israel
Italy
Jordan
Korea Rep
Libya
Malta
Moldova
Morocco
Netherlands
Russian Federation
Saudi Arabia
Slovakia
Slovenia
Spain
Sweden
Switzerland
Tunisia
Turkey
UK
USA
Ex-Yugoslavia

Appendix 4: Countries considered to be "European"

Albania
Andorra
Austria
Belarus
Belgium-Luxembourg
Bosnia-Herzegovina
Bulgaria
Croatia
Cyprus
Ex-Czechoslovakia
Czech Republic
Denmark
Estonia
Faeroe Islands
Finland
France
Germany
Germany DR
Germany FR
Gibraltar
Greece
Hungary
Iceland
Ireland
Italy
Latvia
Lithuania
Macedonia
Malta
Moldova
Netherlands
Norway
Poland
Portugal
Romania
Russian Federation
Slovakia
Slovenia
Spain
Sweden
Switzerland
Ukraine
Ex-USSR
United Kingdom
Yugoslavia
Ex-Yugoslavia

Appendix 5: Exporters of NC sawnwood to Romania in the EFI/WFSE Trade Flow Database

Austria
Belgium-Luxembourg
Canada
France
Germany FR
Germany
Hungary
Ireland
Italy
Malaysia
Moldova
Netherlands
Slovakia
Sweden
Turkey
USA
Yugoslavia

Appendix 6: Exporters of C sawnwood to Romania in the EFI/WFSE Trade Flow Database

Austria
Canada
France
Germany
Greece
Hungary
Italy
Latvia
Moldova
Netherlands
Norway
Russian Fed
Ex-USSR

Appendix 7: A model of trade discrepancies due to intentional underreporting

To simplify the presentation of the model, we focus on discrepancies that result from evasion of import and export duties. We also suppress the subscripts for countries *i* and *j* and ignore measurement error. That is, we assume here, but not in the econometric model, that intentional unreporting of imports or exports is the only source of discrepancies between actual and reported imports and exports: $I^R = I^A - I^{UR}$ and $E^R = E^A - E^{UR}$.

Define the following variables:

p^I	Price of imported sawnwood
τ^I	Import duty (ad valorem)
ϕ^I	Fine on unreported imports (ad valorem)
G^I	Quality of governance in importing country
P	Probability of being caught underreporting imports

The first four variables are given. The fifth is determined by the function

$$P[I^{UR},G],$$

where $P_I = \partial P/\partial I^{UR} > 0$ and $P_G = \partial P/\partial G > 0$: the probability of being caught is greater if more imports are unreported or if the quality of governance in the importing country is higher.

Given an actual amount of imports I^A, we assume that importers select I^{UR} to minimize the expected sum of import duties and fines:

$$\pi \;=\; P(\tau^I p^I I^A + \phi^I p^I I^{UR}) \;+\; (1-P)\,\tau^I p^I I^R\ .$$

With probability P, the importer is caught underreporting imports and pays the import duty $\tau^I p^I$ on the actual amount imported, I^A, and the fine $\phi^I p^I$ on the unreported amount, I^{UR}. With probability 1–P, the importer is not caught and pays only the import duty on the reported quantity imported, I^R. Simplifying, we obtain

$$\pi \;=\; \tau^I p^I I^A \;+\; (P\phi^I - (1-P)\,\tau^I)p^I I^{UR}\ .$$

Finally, if take the derivative with respect to I^{UR}, we obtain the importer's first-order condition,

$$0 \;=\; (P\phi^I - (1-P)\,\tau^I)p^I \;+\; (\phi^I+\tau^I)p^I I^{UR} P_I.$$

We have assumed that the actual amount of imports, I^A, is given, and that the importer only decides how much not to report. Solving for I^{UR}, we obtain a reduced-form expression for the cost-minimizing amount of unreported imports:

$$I^{UR} \;=\; f(p^I,\ \tau^I,\ \phi^I,\ G^I).$$

Unreported imports are a function of import price, import duty, the fine on unreported imports, and quality of governance. From the first-order condition, we expect this expression to include interaction terms like $p^I \tau^I$ and $G^I \tau^I$.

By a similar process, we can derive a reduced-form expression for the cost-minimizing amount of unreported exports:

$$E^{UR} = g(p^E, \tau^E, \phi^E, G^E).$$

Again, we expect this expression to include interaction terms. Combining the two expressions, we obtain a reduced-form expression for the discrepancy due to unreported imports and exports:

$$I^{UR} - E^{UR} = h(p^I, \tau^I, \phi^I, G^I; p^E, \tau^E, \phi^E, G^E).$$

Appendix 8: Additional econometric results

The tables in this appendix show results from intermediate regressions and regressions that we ran to investigate particular issues.

Appendix Tables 8.1-8.6 are results from OLS regressions. In Tables 8.1-8.4, we sequentially add the explanatory variables included in Equation (6). In Table 8.5, we reestimate the standard errors for the model in Table 8.4 using White's method, which is robust to various forms of heteroskedasticity. In Table 8.6, we investigate misclassification of the sawnwood species group by adding the discrepancy for the other species group—DELTA_C in the regression for NC sawnwood; DELTA_NC in the regression for C sawnwood—to the model in Table 8.4.

Appendix Table 8.7 shows estimates from the GLS random effects model. This model includes the same variables as the fixed effects model in Table 7 in the main text.

Appendix Table 8.1. Econometric results (OLS): model with only measurement-error variables.

a. Nonconiferous sawnwood

```
      Source |       SS       df       MS              Number of obs =    6663
-------------+------------------------------           F(  4,  6658) =   87.99
       Model |  44.3212661     4  11.0803165           Prob > F      =  0.0000
    Residual |  838.466214  6658  .125933646           R-squared     =  0.0502
-------------+------------------------------           Adj R-squared =  0.0496
       Total |   882.78748  6662   .13251088           Root MSE      =  .35487

------------------------------------------------------------------------------
       DELTA |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
IM_ADJUST_POS |   .2226108   .0199623    11.15   0.000     .1834783    .2617434
IM_ADJUST_NEG |  -.1820459   .0542762    -3.35   0.001    -.2884446   -.0756472
EX_ADJUST_POS |  -.2930555   .0177847   -16.48   0.000    -.3279193   -.2581917
EX_ADJUST_NEG |   -.144314    .064108    -2.25   0.024    -.2699863   -.0186418
        _cons |   .0288902   .0077532     3.73   0.000     .0136915    .0440889
------------------------------------------------------------------------------
```

b. Coniferous sawnwood

```
      Source |       SS       df       MS              Number of obs =    5286
-------------+------------------------------           F(  4,  5281) =   10.82
       Model |  5.24026607     4  1.31006652           Prob > F      =  0.0000
    Residual |  639.370817  5281  .121070028           R-squared     =  0.0081
-------------+------------------------------           Adj R-squared =  0.0074
       Total |  644.611083  5285  .121969931           Root MSE      =  .34795

------------------------------------------------------------------------------
       DELTA |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
IM_ADJUST_POS |   .1339252   .0230326     5.81   0.000     .0887718    .1790787
IM_ADJUST_NEG |   .0781417   .0811785     0.96   0.336    -.0810017     .237285
EX_ADJUST_POS |   .0320252   .0264509     1.21   0.226    -.0198295    .0838799
EX_ADJUST_NEG |   -.102258   .0975935    -1.05   0.295    -.2935815    .0890655
        _cons |  -.0761233   .0122957    -6.19   0.000     -.100228   -.0520187
------------------------------------------------------------------------------
```

Appendix Table 8.2. Econometric results (OLS): model in Appendix Table 8.1, plus variables for discrepancies in actual (as opposed to reported) trade flows.

a. Nonconiferous sawnwood

Source	SS	df	MS
Model	69.5132138	6	11.5855356
Residual	813.274266	6656	.122186638
Total	882.78748	6662	.13251088

Number of obs =	6663
F(6, 6656) =	94.82
Prob > F =	0.0000
R-squared =	0.0787
Adj R-squared =	0.0779
Root MSE =	.34955

DELTA	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
IM_ADJUST_POS	.2003719	.0197367	10.15	0.000	.1616817	.2390621
IM_ADJUST_NEG	-.1932297	.0534738	-3.61	0.000	-.2980554	-.0884039
EX_ADJUST_POS	-.2965563	.0176032	-16.85	0.000	-.3310642	-.2620484
EX_ADJUST_NEG	-.1452282	.0631769	-2.30	0.022	-.2690752	-.0213812
CONTIGUOUS	-.0834837	.0147978	-5.64	0.000	-.1124922	-.0544753
SWITCH_SIGN	-.5607593	.0431886	-12.98	0.000	-.6454229	-.4760958
_cons	.0298009	.0079986	3.73	0.000	.014121	.0454808

b. Coniferous sawnwood

Source	SS	df	MS
Model	30.3183598	6	5.05305997
Residual	614.292723	5279	.116365358
Total	644.611083	5285	.121969931

Number of obs =	5286
F(6, 5279) =	43.42
Prob > F =	0.0000
R-squared =	0.0470
Adj R-squared =	0.0460
Root MSE =	.34112

DELTA	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
IM_ADJUST_POS	.1024255	.0227442	4.50	0.000	.0578374	.1470136
IM_ADJUST_NEG	.0973021	.0796243	1.22	0.222	-.0587944	.2533986
EX_ADJUST_POS	.0188499	.0259856	0.73	0.468	-.0320927	.0697924
EX_ADJUST_NEG	-.0854017	.0956931	-0.89	0.372	-.2729998	.1021964
CONTIGUOUS	-.052664	.0145237	-3.63	0.000	-.0811364	-.0241916
SWITCH_SIGN	-.6227537	.0442023	-14.09	0.000	-.7094085	-.5360989
_cons	-.0687863	.0124669	-5.52	0.000	-.0932266	-.0443461

Appendix Table 8.3. Econometric results (OLS): model in Appendix Table 8.2, plus variables related to product prices and import barriers.

a. Nonconiferous sawnwood

```
      Source |       SS       df       MS              Number of obs =    6663
-------------+------------------------------           F( 10,  6652) =  125.41
       Model |  140.034571    10  14.0034571           Prob > F      =  0.0000
    Residual |  742.752909  6652  .111658585           R-squared     =  0.1586
-------------+------------------------------           Adj R-squared =  0.1574
       Total |   882.78748  6662   .13251088           Root MSE      =  .33415

------------------------------------------------------------------------------
        DELTA |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
--------------+---------------------------------------------------------------
IM_ADJUST_POS |   .0900454   .0194051     4.64   0.000     .0520051    .1280858
IM_ADJUST_NEG |   -.072678   .0513849    -1.41   0.157    -.1734089    .0280529
EX_ADJUST_POS |  -.1530481   .0177745    -8.61   0.000    -.1878917   -.1182044
EX_ADJUST_NEG |  -.2226085   .0605058    -3.68   0.000    -.3412193   -.1039977
   CONTIGUOUS |  -.0957467   .0141899    -6.75   0.000    -.1235634     -.06793
  SWITCH_SIGN |  -.4893289   .0414478   -11.81   0.000    -.5705797    -.408078
      IM_DUTY |  -.0934472   .2011569    -0.46   0.642    -.4877792    .3008847
      IM_UVAL |  -.0003677   .0000161   -22.83   0.000    -.0003993   -.0003361
 IM_DUTYxUVAL |   .0008785   .0003472     2.53   0.011      .000198     .001559
      EX_UVAL |   .0003553   .0000179    19.89   0.000     .0003202    .0003903
        _cons |   .0496078   .0105527     4.70   0.000      .028921    .0702945
------------------------------------------------------------------------------
```

b. Coniferous sawnwood

```
      Source |       SS       df       MS              Number of obs =    5286
-------------+------------------------------           F( 10,  5275) =   68.18
       Model |  73.7841605    10  7.37841605           Prob > F      =  0.0000
    Residual |  570.826922  5275  .108213635           R-squared     =  0.1145
-------------+------------------------------           Adj R-squared =  0.1128
       Total |  644.611083  5285  .121969931           Root MSE      =  .32896

------------------------------------------------------------------------------
        DELTA |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
--------------+---------------------------------------------------------------
IM_ADJUST_POS |   .0097482   .0225152     0.43   0.665    -.0343909    .0538874
IM_ADJUST_NEG |   .1459766    .076898     1.90   0.058    -.0047753    .2967286
EX_ADJUST_POS |   .0499123    .025204     1.98   0.048     .0005021    .0993225
EX_ADJUST_NEG |   -.049975   .0923158    -0.54   0.588    -.2309521    .1310021
   CONTIGUOUS |  -.0722778   .0140933    -5.13   0.000    -.0999065   -.0446491
  SWITCH_SIGN |  -.5203312     .04296   -12.11   0.000    -.6045506   -.4361117
      IM_DUTY |   .2401215   .2656948     0.90   0.366    -.2807502    .7609932
      IM_UVAL |  -.0006178   .0000401   -15.42   0.000    -.0006963   -.0005393
 IM_DUTYxUVAL |  -.0001077   .0008009    -0.13   0.893    -.0016777    .0014624
      EX_UVAL |   .0006759   .0000355    19.03   0.000     .0006063    .0007455
        _cons |  -.0428256   .0145213    -2.95   0.003    -.0712934   -.0143577
------------------------------------------------------------------------------
```

Appendix Table 8.4. Econometric results (OLS): model in Appendix Table 8.3, plus institutional-quality variables. Note: this model includes the same variables as in Table 7.

a. Nonconiferous sawnwood

Source	SS	df	MS
Model	140.118846	13	10.7783728
Residual	683.822933	6126	.111626336
Total	823.941779	6139	.134214331

Number of obs	6140
F(13, 6126)	96.56
Prob > F	0.0000
R-squared	0.1701
Adj R-squared	0.1683
Root MSE	.33411

DELTA	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
IM_ADJUST_POS	.0954195	.0199473	4.78	0.000	.0563157	.1345233
IM_ADJUST_NEG	-.0908251	.0534677	-1.70	0.089	-.1956406	.0139904
EX_ADJUST_POS	-.1367901	.0183609	-7.45	0.000	-.172784	-.1007963
EX_ADJUST_NEG	-.2434468	.0635586	-3.83	0.000	-.3680441	-.1188496
CONTIGUOUS	-.0793072	.0153976	-5.15	0.000	-.1094919	-.0491226
SWITCH_SIGN	-.4836388	.0431718	-11.20	0.000	-.5682707	-.399007
IM_DUTY	.0185315	.2134044	0.09	0.931	-.399816	.436879
IM_UVAL	-.0003669	.0000165	-22.25	0.000	-.0003992	-.0003346
IM_DUTYxUVAL	-.0011345	.0012317	-0.92	0.357	-.003549	.0012801
EX_UVAL	.0003609	.0000185	19.56	0.000	.0003247	.000397
IM_GOV	-.0047617	.0045266	-1.05	0.293	-.0136354	.0041121
IM_DUTYxGOV	.000421	.0002428	1.73	0.083	-.000055	.000897
EX_GOV	-.0219924	.0033324	-6.60	0.000	-.0285251	-.0154598
_cons	.1651611	.0282622	5.84	0.000	.1097573	.220565

b. Coniferous sawnwood

Source	SS	df	MS
Model	68.4939343	13	5.26876418
Residual	512.075852	4772	.107308435
Total	580.569786	4785	.121331199

Number of obs	4786
F(13, 4772)	49.10
Prob > F	0.0000
R-squared	0.1180
Adj R-squared	0.1156
Root MSE	.32758

DELTA	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
IM_ADJUST_POS	-.0082837	.0237422	-0.35	0.727	-.0548295	.038262
IM_ADJUST_NEG	.1765369	.0806718	2.19	0.029	.018383	.3346908
EX_ADJUST_POS	.0287068	.0265075	1.08	0.279	-.0232601	.0806737
EX_ADJUST_NEG	.103974	.1087559	0.96	0.339	-.1092377	.3171857
CONTIGUOUS	-.0639322	.0150991	-4.23	0.000	-.0935334	-.0343309
SWITCH_SIGN	-.5242962	.0442852	-11.84	0.000	-.6111156	-.4374768
IM_DUTY	-.0182552	.2848618	-0.06	0.949	-.5767156	.5402052
IM_UVAL	-.0005795	.0000419	-13.82	0.000	-.0006618	-.0004973
IM_DUTYxUVAL	-.0074588	.0031927	-2.34	0.020	-.0137181	-.0011996
EX_UVAL	.00065	.0000367	17.71	0.000	.0005781	.000722
IM_GOV	-.0063259	.0045749	-1.38	0.167	-.0152949	.002643
IM_DUTYxGOV	.0016631	.0006751	2.46	0.014	.0003396	.0029866
EX_GOV	-.0278795	.0045683	-6.10	0.000	-.0368356	-.0189235
_cons	.1459732	.0339705	4.30	0.000	.0793753	.212571

Appendix Table 8.5. Econometric results (OLS): model in Appendix Table 8.4, estimated with robust standard errors.

a. Nonconiferous sawnwood

Regression with robust standard errors

Number of obs	= 6140
F(13, 6126)	= 84.93
Prob > F	= 0.0000
R-squared	= 0.1701
Root MSE	= .33411

DELTA	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
IM_ADJUST_POS	.0954195	.021835	4.37	0.000	.0526152	.1382238
IM_ADJUST_NEG	-.0908251	.0544603	-1.67	0.095	-.1975864	.0159363
EX_ADJUST_POS	-.1367901	.0219034	-6.25	0.000	-.1797285	-.0938517
EX_ADJUST_NEG	-.2434468	.0790178	-3.08	0.002	-.3983496	-.0885441
CONTIGUOUS	-.0793072	.0119305	-6.65	0.000	-.1026953	-.0559192
SWITCH_SIGN	-.4836388	.0338148	-14.30	0.000	-.5499277	-.4173499
IM_DUTY	.0185315	.1998459	0.09	0.926	-.3732367	.4102996
IM_UVAL	-.0003669	.0000199	-18.46	0.000	-.0004058	-.0003279
IM_DUTYxUVAL	-.0011345	.0013036	-0.87	0.384	-.00369	.0014211
EX_UVAL	.0003609	.0000257	14.03	0.000	.0003105	.0004113
IM_GOV	-.0047617	.0046672	-1.02	0.308	-.013911	.0043876
IM_DUTYxGOV	.000421	.0002556	1.65	0.100	-.0000801	.0009221
EX_GOV	-.0219924	.0034685	-6.34	0.000	-.028792	-.0151929
_cons	.1651611	.0290812	5.68	0.000	.1081518	.2221704

b. Coniferous sawnwood

Regression with robust standard errors

Number of obs	= 4786
F(13, 4772)	= 37.30
Prob > F	= 0.0000
R-squared	= 0.1180
Root MSE	= .32758

DELTA	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
IM_ADJUST_POS	-.0082837	.0283349	-0.29	0.770	-.0638332	.0472658
IM_ADJUST_NEG	.1765369	.1045526	1.69	0.091	-.0284344	.3815083
EX_ADJUST_POS	.0287068	.0303439	0.95	0.344	-.0307812	.0881948
EX_ADJUST_NEG	.103974	.1449896	0.72	0.473	-.1802726	.3882206
CONTIGUOUS	-.0639322	.0115379	-5.54	0.000	-.0865519	-.0413125
SWITCH_SIGN	-.5242962	.0414657	-12.64	0.000	-.6055881	-.4430043
IM_DUTY	-.0182552	.2626383	-0.07	0.945	-.5331474	.496637
IM_UVAL	-.0005795	.0000525	-11.04	0.000	-.0006824	-.0004766
IM_DUTYxUVAL	-.0074588	.0030462	-2.45	0.014	-.0134308	-.0014868
EX_UVAL	.00065	.000056	11.61	0.000	.0005403	.0007598
IM_GOV	-.0063259	.0052321	-1.21	0.227	-.0165834	.0039315
IM_DUTYxGOV	.0016631	.0007257	2.29	0.022	.0002405	.0030858
EX_GOV	-.0278795	.0049831	-5.59	0.000	-.0376488	-.0181103
_cons	.1459732	.0390439	3.74	0.000	.0694291	.2225173

Appendix Table 8.6. Econometric results (OLS): model in Appendix Table 8.4, plus discrepancy for sawnwood of opposite species group

a. Nonconiferous sawnwood

Source	SS	df	MS
Model	141.09308	14	10.0780772
Residual	682.848699	6125	.111485502
Total	823.941779	6139	.134214331

Number of obs =	6140
F(14, 6125) =	90.40
Prob > F =	0.0000
R-squared =	0.1712
Adj R-squared =	0.1693
Root MSE =	.33389

DELTA	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
IM_ADJUST_POS	.0924462	.0199601	4.63	0.000	.0533174	.1315751
IM_ADJUST_NEG	-.0866075	.053453	-1.62	0.105	-.1913941	.0181792
EX_ADJUST_POS	-.1359605	.0183515	-7.41	0.000	-.1719359	-.0999852
EX_ADJUST_NEG	-.245051	.0635209	-3.86	0.000	-.3695742	-.1205278
CONTIGUOUS	-.076721	.0154127	-4.98	0.000	-.1069353	-.0465067
SWITCH_SIGN	-.4805571	.0431571	-11.14	0.000	-.5651602	-.3959539
IM_DUTY	.0161204	.2132713	0.08	0.940	-.4019662	.4342071
IM_UVAL	-.0003655	.0000165	-22.18	0.000	-.0003979	-.0003332
IM_DUTYxUVAL	-.0010992	.001231	-0.89	0.372	-.0035124	.001314
EX_UVAL	.0003592	.0000184	19.47	0.000	.000323	.0003953
IM_GOV	-.0043874	.0045255	-0.97	0.332	-.0132591	.0044842
IM_DUTYxGOV	.0004149	.0002427	1.71	0.087	-.0000608	.0008906
EX_GOV	-.021807	.0033309	-6.55	0.000	-.0283367	-.0152773
DELTA_C	.0368049	.0124504	2.96	0.003	.0123977	.061212
_cons	.1625302	.0282584	5.75	0.000	.1071338	.2179265

b. Coniferous sawnwood

Source	SS	df	MS
Model	69.4255084	14	4.95896489
Residual	511.144278	4771	.107135669
Total	580.569786	4785	.121331199

Number of obs =	4786
F(14, 4771) =	46.29
Prob > F =	0.0000
R-squared =	0.1196
Adj R-squared =	0.1170
Root MSE =	.32732

DELTA	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
IM_ADJUST_POS	-.0073934	.023725	-0.31	0.755	-.0539055	.0391186
IM_ADJUST_NEG	.1753936	.0806077	2.18	0.030	.0173652	.3334219
EX_ADJUST_POS	.0417553	.0268533	1.55	0.120	-.0108895	.0944001
EX_ADJUST_NEG	.1070061	.1086732	0.98	0.325	-.1060434	.3200557
CONTIGUOUS	-.0588746	.0151841	-3.88	0.000	-.0886425	-.0291067
SWITCH_SIGN	-.526029	.0442534	-11.89	0.000	-.6127862	-.4392719
IM_DUTY	-.0341913	.2846837	-0.12	0.904	-.5923026	.52392
IM_UVAL	-.0005741	.000042	-13.68	0.000	-.0006563	-.0004918
IM_DUTYxUVAL	-.0078337	.0031927	-2.45	0.014	-.0140928	-.0015745
EX_UVAL	.0006532	.0000367	17.80	0.000	.0005813	.0007252
IM_GOV	-.0063372	.0045712	-1.39	0.166	-.0152989	.0026246
IM_DUTYxGOV	.0017381	.000675	2.57	0.010	.0004148	.0030615
EX_GOV	-.0290043	.0045806	-6.33	0.000	-.0379843	-.0200243
DELTA_NC	.0366893	.0124422	2.95	0.003	.0122968	.0610818
_cons	.14316	.0339565	4.22	0.000	.0765895	.2097304

Appendix Table 8.7. Econometric results (GLS, random effects): model in Appendix Table 8.4. Note: this model includes the same variables as in Table 7.

a. Nonconiferous sawnwood

```
Random-effects GLS regression                   Number of obs      =      6140
Group variable (i): IDnum                       Number of groups   =      1058

R-sq:  within  = 0.2173                         Obs per group: min =         1
       between = 0.0887                                        avg =       5.8
       overall = 0.1572                                        max =        16

Random effects u_i ~ Gaussian                   Wald chi2(13)      =   1517.27
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000
```

DELTA	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
IM_ADJUST_POS	.0493749	.0217899	2.27	0.023	.0066675	.0920823
IM_ADJUST_NEG	-.0271619	.0466818	-0.58	0.561	-.1186566	.0643328
EX_ADJUST_POS	-.0987985	.0184627	-5.35	0.000	-.1349846	-.0626123
EX_ADJUST_NEG	-.1239	.056296	-2.20	0.028	-.2342382	-.0135619
CONTIGUOUS	-.112042	.0357177	-3.14	0.002	-.1820474	-.0420367
SWITCH_SIGN	-.6068356	.034538	-17.57	0.000	-.6745289	-.5391424
IM_DUTY	.2767382	.1952787	1.42	0.156	-.106001	.6594775
IM_UVAL	-.0003451	.0000152	-22.65	0.000	-.0003749	-.0003152
IM_DUTYxUVAL	-.0020978	.0011462	-1.83	0.067	-.0043443	.0001488
EX_UVAL	.0003743	.0000165	22.71	0.000	.000342	.0004066
IM_GOV	-.0054136	.0067484	-0.80	0.422	-.0186402	.007813
IM_DUTYxGOV	.0005243	.0002237	2.34	0.019	.0000858	.0009627
EX_GOV	.0031549	.0056492	0.56	0.577	-.0079172	.0142271
_cons	.0448719	.0436502	1.03	0.304	-.040681	.1304248
sigma_u	.25877172					
sigma_e	.24280513					
rho	.53180057	(fraction of variance due to u_i)				

b. Coniferous sawnwood

```
Random-effects GLS regression                   Number of obs      =      4786
Group variable (i): IDnum                       Number of groups   =       781

R-sq:  within  = 0.1671                         Obs per group: min =         1
       between = 0.0609                                        avg =       6.1
       overall = 0.1063                                        max =        16

Random effects u_i ~ Gaussian                   Wald chi2(13)      =    846.13
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
       DELTA |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
IM_ADJUST_POS | -.0096555   .0288387    -0.33   0.738    -.0661782    .0468673
IM_ADJUST_NEG |  .1805005   .0668914     2.70   0.007     .0493959    .3116051
EX_ADJUST_POS |  .0101717   .0261072     0.39   0.697    -.0409975    .0613409
EX_ADJUST_NEG |   .012453   .0994981     0.13   0.900    -.1825597    .2074658
   CONTIGUOUS | -.0803034   .0360459    -2.23   0.026     -.150952   -.0096547
  SWITCH_SIGN | -.6251111   .0364122   -17.17   0.000    -.6964777   -.5537445
      IM_DUTY | -.6725033   .2833796    -2.37   0.018    -1.227917   -.1170896
      IM_UVAL | -.0006669   .0000392   -17.02   0.000    -.0007437   -.0005902
 IM_DUTYxUVAL |  -.009734   .0031337    -3.11   0.002     -.015876   -.0035919
      EX_UVAL |  .0006189   .0000343    18.05   0.000     .0005517    .0006861
       IM_GOV |  .0062385   .0072222     0.86   0.388    -.0079168    .0203938
  IM_DUTYxGOV |   .002421    .000649     3.73   0.000      .001149     .003693
       EX_GOV |  .0016462   .0079234     0.21   0.835    -.0138834    .0171757
        _cons | -.0257001   .0530792    -0.48   0.628    -.1297334    .0783333
-------------+----------------------------------------------------------------
      sigma_u | .26224993
      sigma_e |  .2448774
          rho |  .5342166   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```