World Trade in Used Automobiles:

A Gravity Analysis of Japanese and US Exports[1]

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Abstract—We estimate a gravity model of Japanese and US exports of used automobiles that incorporates an original, ordered measure of protection in global, used automobile markets. The model confirms that, overall, protection by our measure is suppressive and often statistically significant and that what we term "Grubel income effects" are present. However, Japanese export behavior appears to differ in some important respects from that of the United States, with distance and protection levels being less significant and left-hand side driving patterns being a critical explanatory variable.

Keywords: Gravity models, protection, used automobiles
JEL Categories: F13, F14, C20

1. Introduction

The economic analysis of world trade in used durable goods began with the contribution of Sen (1962). This literature subsequently included Smith (1974 and 1976), Pack (1978), Bond (1983), and Navaretti, Soloaga and Takacs (2000). Taken as a whole, these contributions suggest that developing countries would benefit from increased trade in used durable goods. This gain reflects the fact that these goods are labor intensive in their use, maintenance, and repair relative to new durable goods. Labor-abundant, developing countries are therefore better able to utilize them than labor-scarce, developed countries.

The specific case of used automobiles was first examined by Grubel (1980). He emphasized the slowly-depreciating nature of automobiles in developing countries in explaining the potential gains from trade. Lying dormant for some time, the subject of used automobile trade was taken up by Pelletiere and Reinert (2002 and 2004) who analyzed the used automobile exports of the United States and by Clerides (2003) who analyzed the used automobile imports of Cyprus.[2] In this paper, we are more comprehensive, analyzing the used automobile exports of both Japan and the United States. Specifically, we estimate a gravity model of these exports, utilizing an original measure of used automobile protection in 121 importing countries of the world. We

[2] See also Panagariya (2000).

consider the used automobile exports of these two countries separately for the year 2001, the first year for which Japanese used automobile export data were available.

Our results confirm that, in general, protection in world used automobile markets tends to be statistically significant and that what we term "Grubel income effects" are present. However, Japanese export behavior appears to differ in some important respects from that of the United States, with distance and protection levels being less significant and left-hand side driving patterns being a critical explanatory variable.[3]

2. Used Automobile Protection Data

Until recently, there has been no comprehensive and consistent database on protection levels against used automobile imports. For this paper, we have compiled such a database for the year 2001 using a variety of sources. These sources include the International Trade Administration of the US Department of Commerce, the US Department of State, and the US government's Trade Information Center. These were supplemented with a review of World Trade Organization (WTO) documents, with reports emanating from the Trade Policy Review Mechanism being a noteworthy source. Reviews of international business and trade press reports, country customs information, and other government sources were used to provide additional information and, where possible, determine the nature of policies and the timing of policy changes. In a few cases, formal responses to a survey administered to commercial attaches and follow-up phone interviews were used to further check the reports of published sources. In cases where a clear determination of protective measures was not possible, the country was excluded from further consideration.

Since most used automobile restrictions include non-tariff measures of a various and creative nature, it was not possible to construct a *continuous* measure of protection. Instead, we mapped the policies onto an *ordinal* scale ranging from 0 to 3 with 2001 as a common focus year. This measure is best viewed as a discrete indicator for a *latent* and continuous protection variable that is too difficult to measure as such. Each score contains a subset of policies deemed to be more restrictive than those assigned to the

[3] This refers to the side of the road the vehicle drives on.

previous score. The ordinal scale is presented in Table 1, along with the number of countries falling into the category.

A value of 0 in Table 1 indicates that there are minimal restrictions on imports of used automobiles with little differentiation between new and used automobile protection. Generally, import valuation takes place based on market values such as those of the "Blue Book." For example, a value of 1 in Table 1 indicates the existence of a clear and discriminatory restriction, however slight, to the import of used automobiles vis-à-vis new automobiles. These measures include age-based tax escalation, capped depreciation, and age limits of 6 years or older. A value of 2 in Table 1 indicates a relatively high degree of protection against imports of used automobiles. These measures include age limits of 5 years or less and even a requirement that the automobiles be disassembled before importation. Finally, a value of 3 in Table 1 indicates that imports of used automobiles are prohibited.

We have utilized this ordinal protection measure in a gravity model of Japanese and US exports of used automobiles to which we now turn.

3. Gravity Model Specification

We model the used automobile exports of Japan and the United States in the year 2001 using two alternative gravity models.[4] The first model takes as its dependent variable the log of used automobile exports of Japan and the United States. The second model takes as its dependent variable a transformation of used automobile exports as a proportion of total automobile exports. In both of these models, the export data are in unit rather than value terms. In the first case, we model exports from either Japan or the United States ($i = Japan, United\ States$) to the set of importing countries in our sample ($j = 1,...,n$) using the following equation:

[4] The gravity model has a very large literature going back to an initial burst of published literature appearing in the mid-1960s (Tinbergen, 1962; Linnenman, 1966; Leamer and Stern, 1970 and 1974; Aitken 1973). For an important, recent contribution, see Feenstra, Markusen, and Rose (2001). The theoretical foundations of the gravity equation are well established under alternative assumptions (see Anderson, 1979; Bergstrand, 1985, 1989, 1990; Helpman and Krugman, 1985; Deardorff, 1998.)

$$\ln e_{ij} = \alpha_0 + \alpha_1 \ln gdp_j + \alpha_2 \ln pop_j + \alpha_3 \ln dist_{ij} + \alpha_4 protect_{ij} + \alpha_5 left_j + \alpha_6 europe_j + \varepsilon_{ij} \quad (1)$$

In this equation, e_{ij} is the exports of either Japan or the United Sates to importing country j as measured by the Japanese Customs and Tariff Bureau and the US International Trade Commission. The first right-hand side variable is the natural log of GDP in country j as measured by 2001 World Bank purchasing power parity (PPP) data.[5] Representing total income in country j, the sign of this variable is expected to be positive.

The second right-hand side variable is the natural log of 2001 population of country j as measured by World Bank data. The sign of this variable is expected to be negative because increases in population reduce measured, per-capita income. The third right-hand side variable is the natural log of distance from country i to country j, as measured between capital cities. Data for this variable are taken from "How Far Is It?" which uses data from the US Census and a supplementary list of cities around the world to find the latitude and longitude of two places to calculate the straight-line distance between them.[6] Its expected sign is negative.

The fourth right-hand side variable is a dummy variable relating to the ordinal protection measure described in Section 2. We expect this variable to have a negative sign. The fifth right-hand side variable is a dummy variable for left-hand side driving patterns. We expect this dummy to have a negative sign for the United States and a positive sign for Japan.[7] The last right-hand side variable in Equation 1 is a dummy for destination countries that are in Europe, which has its own well-developed, regional market in used automobiles. We expect the sign of this variable to be negative.

In the second specification, we model exports from either Japan or the United States to the set of importing countries in our sample using the following equation:

[5] In some cases where World Bank data are not available (e.g., Taiwan), we use US Central Intelligence Agency World Fact Book estimates.
[6] See http://www.indo.com/distance/.
[7] In an Appendix to this paper, we provide a list of the left-hand side and right-hand side driving countries in our sample.

$$\ln\left[prop_{ij} \Big/ \left(1 - prop_{ij}\right) \right] = \beta_0 + \beta_1 \ln\left(gdp_j \Big/ pop_j \right) + \beta_2 \ln dist_{ij} + \beta_3 protect_j$$
$$+ \beta_4 left_j + \beta_5 europe_j + \upsilon_{ij} \qquad (2)$$

The left-hand side of Equation 2 is a transformed measure of $prop_{ij}$, the proportion of 2001 automobile exports from Japan or the United States to country j consisting of used automobiles. The left-hand side transforms $prop_{ij}$ as $\ln\left[prop_{ij} \Big/ \left(1 - prop_{ij}\right) \right]$ to overcome the bounded nature of the proportion measure $prop_{ij}$. The purpose of examining $prop_{ij}$ is to test an assertion of Grubel (1980), namely, that there is an inverse relationship between per-capita incomes and the demand for used automobiles relative to new automobiles. We refer to this as the "Grubel income effect."

The first right-hand side variable in Equation 2 is GDP per capita as measured by World Bank data. The second through fifth right-hand side variables are all the same as in Equation 1. Here, our expected sign for the natural log of distance is again negative due to expected Alchian and Allen effects, namely that a fixed charge added to two similar goods of different quality will reduce the *relative* cost of the higher quality, more expensive good, and therefore increase its share of demand.[8] Thus we expect distance to increase the share of new automobiles and reduce $prop_{ij}$. Along with Allen and Alchian effects, we clearly expect ordinal protection, a measure of discrimination against used automobiles that raises the price of used automobiles relative to new, to have a negative impact on the proportion of used automobiles relative to new in a country's imports. We also have the same expected sign for the left-hand side driving variable as in Equation 1. However, we no longer have expected signs for the Europe dummy variable. A country's

[8] The traditional example is the effect of adding shipping costs to apples produced in Washington State. The Alchian and Allen theorem first appeared in print in Alchian and Allen's *University Economics* (1964), and it was immediately challenged (Gould and Segall, 1969). A 1975 letter-to-the-editor exchange in the *Seattle Times* on why the apples in Washington seemed to be of lower quality than the Washington State apples purchased in distant states, led to renewed interest in the subject, starting with Borchering and Silberberg (1978). They argue that the theorem works in the special case where the goods are close substitutes. Used and new automobiles appear to be a valid test case. Bauman (2004) has since suggested that by carefully considering the units and the nature of the costs, the theorem can be more widely applied.

presence in Europe might affect both the numerator and denominator of $prop_{ij}$ in the same way. This was not the case with e_{ij} in Equation 1.

4. Descriptive Statistics

Before turning to the results of our estimation, it is useful to briefly consider some descriptive statistics on Japanese and US used automobile exports. Doing so will reveal that the export markets for these two countries, whether for used or new automobiles or both, differ primarily in trade volume rather than other relevant characteristics. The descriptive statistics are presented in Table 2. Japan's mean used exports in units across all destination countries is more than three times that of the United States, and its maximum exports is nearly three times that of the United States. This might indicate that Japan is more export oriented than the United States in used automobiles, but this is not the case. In fact, the proportion of automobile exports that is used is actually slightly less in Japan than in the United States with a higher standard deviation suggesting greater variation across importing countries. As shown by the data, Japan's greater export orientation is in automobiles of all kinds, both new and used. Japan's used automobile exports do differ slightly from the United States in that the mean distance to market (capital to capital) is approximately 1,000 miles greater.

The descriptive statistics for population, protection, and left-hand drive dummies, described above, are virtually identical. This reflects the fact that the exports of both countries are widely distributed across nearly the same set of destination countries. The differences in GDP largely reflect the exclusion of the US, with its great weight, in the US statistics. In general, Japan appears to be located at a significantly greater distance from its markets.

However, while both countries export to left-hand driving markets, *a priori*, left-hand side driving does appear to affect export *volumes* for Japan and the US. Japan exports a mean of 3,176 used automobiles per country on the whole but a mean of 7,600 to countries with left-hand side driving. For the US, the average used auto export volume is 977 but for left-hand drive countries this declines to 399. More telling, however, the median exports of used automobiles from Japan to left-hand drive countries is 1842 while

for the US it is merely 4. This compares to 12 and 30 respectively for used automobile exports to all countries. This is to prove important in our estimated results.

5. Estimation Results

The estimation results for the gravity models of Equations 1 and 2 are presented in Table 3. This estimation utilizes the HC3 procedure for producing heteroskedasticy-consistent standard errors.[9] Columns 1 and 2 present results for Equation 1 (gross exports) as applied to the used automobile exports of the United States. Column 1 takes as its protective measure a dummy variable indicating that the ordinal variable described in Table 1 has a value of 2 or 3, while column 2 takes as its protective measure a dummy variable indicating that this ordinal variable has a value of 3. In these two columns, the GDP, population, distance, drive on left, Europe and protection variables are all of the expected signs and are statistically significant.

Columns 3 and 4 present the results for Equation 2 (export proportion) as applied to the exports of the United States. The GDP per capita variable has a negative sign and is statistically significant, confirming the Grubel income effect discussed above. The distance variable also has the expected sign and is statistically significant. The drive on left and Europe variables are not statistically significant for these estimates. As mentioned above, we had no expected sign for the Europe dummy in Equation 2. Finally, the protection variable has the expected sign in Columns 3 and 4, but it is not statistically significant in Column 4.

Columns 5 and 6 present results for Equation 1 (gross exports) as applied to the used automobile exports of the Japan. Column 5 takes as its protective measure a dummy variable indicating that the ordinal variable described in Table 1 has a value of 2 or 3, while column 6 takes as its protective measure a dummy variable indicating that this ordinal variable has a value of 3. In these two columns, the GDP and population variables are of the expected sign, although the latter are not statistically significant. Unlike the United States, the distance variables are of the wrong sign, although they are not statistically significant. The drive on left variables are of the expected sign, are statistically significant, and are larger in absolute value than that of the United States. The

[9] See White (1980), MacKinnon and White (1985), and Long and Ervin (2000).

Europe dummy has the expected sign, although it is only statistically significant in column 6. Finally, although the protection dummies are of the expected sign, they too are not statistically significant. Columns 5 and 6 thus indicate that the used automobile export behavior of Japan differs from that of the United States. More specifically, left-hand side driving is more important for Japan as a positive influence on export volumes than it is for the United States as a negative influence on export volumes, Japan being the only significant exporter of left-hand drive used automobiles outside of the UK in Europe.

Columns 7 and 8 present the results for Equation 2 (export proportion) as applied to the exports of Japan. As with the case of the United States, the results of two columns confirm the Grubel income effect for the case of Japan's used automobile exports. Distance again has an unexpected sign, although it is not statistically significant. The Europe and protection measures are also not statistically significant. Most important as an explanatory variable, once again, is the left-hand side driving variable, with approximately the same order of magnitude as the case of gross exports.

6. Conclusion

International markets in used automobiles are fairly well developed, but protection measures in these markets are very common. Accounting for both trade and protection in world used automobile markets shows that these markets can be accounted for in a gravity model framework and that protection levels do tend to have a suppressing effect on trade. That said, however, US and Japanese exports appear to behave differently. Exports from the US appear to conform well to the gravity framework and as expected with regard to Alchian and Allen effects in the proportions model. For Japan the signs are as expected for GDP, importing-country population, left-hand side driving, the Europe dummy, and protection in the gross exports model. Only GDP, left-hand drive, and the Europe dummy, however, appear significant. In the proportions model, the signs are as expected for GDP per capita and protection, with the Europe dummy negative as in the case of the US, but only GDP per capita and left-hand side driving are statistically significant. Distance is an unexpectedly positive but insignificant variable in predicting Japan's exports in both models. This appears to be due, in part, to the overriding

importance of left-hand side driving patterns in defining and limiting the market for this country's used automobile exports.

Another related factor is Japan's environmental and safety regulatory regime. The Japanese regime, despite some liberalization, continues to be much less tolerant of used automobiles than that in the US regime. In Japan, automobiles are subject to a costly inspection and maintenance regime that serves to substantially increase the rate at which vehicles depreciate for consumers in Japan. This limits the used market in Japan, which in turn has been speculated to generate a "push" of Japanese vehicles into the world market, where they may have a significantly higher value relative to used automobile imports from other countries without such restrictive regimes. Such a "push" effect is not explicit in our model or in the descriptive statistics of Table 2, but we can speculate that the variation in domestic regulation as a cause for the variation in the factors influencing the two countries' export behavior.

The analysis in this paper utilizes Japanese and US used automobile export data for the first year in which the Japanese used automobile export data are available, namely 2001. As a longer time series for these data emerge, it will be possible to re-estimate the models of this paper with panel data or with data averaged over, say, a three-year period, as is currently possible with the US data (Pelletiere and Reinert, 2004). This will help to ensure that the results do not merely reflect the idiosyncrasies of a particular year. However, we do believe that the results of this paper suggest significant differences between the two major used automobile exports of the world economy and contribute to our evolving understanding of used, durable goods markets.

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Table 1. An Ordinal Measure of Used Automobile Protection, 2001

Ordinal Measure	Policy Summaries	Protection Measure Only (n = 130)	Number Included in Estimation (n = 121)
0	No additional restrictions on imports or "Blue Book" valuation applied.	61	56
1	Taxes escalate with the age of the vehicle; capped depreciation; age limit of 6 years or older applied; or a small additional fee/duty.	24	22
2	Age limits of 5 years or fewer applied; cannot be imported fully assembled; or a combination of these or lesser restrictions.	25	23
3	Imports prohibited; required import licenses not being approved.	20	20

Notes: Numbers included in the estimation reflects measures for Japanese exports. The ordinal measures can differ for US and Japanese exports due to special conditions and incentives accorded to one or the other exporter. Details of these modifications are available from the authors.

Table 2. Descriptive Statistics for Japanese and US Automobile Exports, 2001

Japanese Exports

	N	Minimum	Maximum	Mean	Std. Deviation
New autos (units)	121	0	1,757,244	25,748	161,667
Used autos (units)	121	0	112,345	3,176	11,691
GDP (US$ million)	121	528	10,019,700	216,411	946,043
Population (thousand)	121	247	1,271,850	45,546	151,294
Distance (capital to capital, miles)	121	1,303	11,544	6,450	2,180
Protect	121	0	3	1.058	1.150
Drive on Left	121	0	1	0.27	0.45
Prop[a]	119	0	1	0.29	0.38

US Exports

	N	Minimum	Maximum	Mean	Std. Deviation
New autos (units)	122	0	833,441	11,257	78,440
Used autos (units)	122	0	39,034	977	4,143
GDP (US$ million)	122	528	4,175,600	166,747	469,884
Population (thousand)	122	247	1,271,850	43,910	149,304
Distance (capital to capital, miles)	122	455	10,163	5,418	2,265
Protect	122	0	3	1.033	1.128
Drive on Left	122	0	1	0.28	0.45
Prop[a]	117	0	1	0.31	0.29

[a]Prop is the proportion of 2001 automobile exports from Japan or the United States to country j consisting of used automobiles.

Table 3. Gravity Model Results

	1	2	3	4	5	6	7	8
	US	**US**	**US**	**US**	**Japan**	**Japan**	**Japan**	**Japan**
Variable/Measure	**Gross exports**	**Gross exports**	**Export proportion**	**Export proportion**	**Gross exports**	**Gross exports**	**Export proportion**	**Export proportion**
Constant	5.093 (3.208)	6.620 (3.484)	10.510** (3.032)	11.286** (3.081)	-10.991 (9.254)	-13.318 (9.986)	-5.507 (7.494)	-5.681 (7.409)
Lngdp	.933** (.118)	.900** (.124)			.645** (.193)	.689** (.180)		
Lnpop	-.321* (.143)	-.326* (.148)			-.249 (.242)	-.205 (.243)		
Ln(gdp/pop)			-.650** (.098)	-.675** (.101)			-.962** (.205)	-.964** (.205)
Lndist	-2.041** (.360)	-2.144** (.353)	-.743* (.356)	-.836* (.359)	.275 (.753)	.359 (.812)	1.056 (.772)	1.079 (.757)
Left	-.792* (.372)	-1.093* (.353)	.100 (.357)	-.078 (.379)	4.763** (.536)	4.599** (.488)	4.839** (.557)	4.733** (.530)
Europe	-1.787** (.420)	-1.616** (.450)	-.220 (.346)	-.074 (.339)	-1.504 (.982)	-1.768* (.843)	-.548 (1.11)	-.567 (1.018)
Protect = 2,3	-1.220** (.360)		-.932** (.322)		-.229 (.844)		-.257 (.735)	
Protect = 3		-1.110** (.533)		-.751 (.497)		-1.043 (.942)		-.440 (.914)
R-squared	.656	.633	.410	.378	.449	.458	.575	.576
Observations	121	121	107	107	120	120	97	97

Notes: "*" denotes significance at the 5 percent level, "**" denotes significance at the 1 percent level, and HC3 heteroskedasticity-consistent standard errors are reported in parentheses. See Long and Ervin (2000).

Appendix. Left-Hand and Right-Hand Side Drive Countries in Sample, 2001

Left-Hand Side	Right-Hand Side	Right-Hand Side	Right-Hand Side
Australia	Algeria	Georgia	Qatar
Bahamas	Argentina	Germany	Romania
Bangladesh	Austria	Ghana	Russia
Barbados	Bahrain	Greece	Saudi Arabia
Bhutan	Belarus	Guatemala	Senegal
Botswana	Belgium	Guinea	Slovenia
Guyana	Belize	Haiti	Spain
Hong Kong	Benin	Honduras	Sweden
India	Bolivia	Hungary	Switzerland
Indonesia	Brazil	Israel	Syria
Ireland	Bulgaria	Italy	Taiwan
Jamaica	Burkina Faso	Ivory Coast	Togo
Kenya	Cameroon	Jordan	Tunisia
Lesotho	Canada	Kazakhstan	Turkey
Malawi	Chad	Kuwait	Ukraine
Malaysia	Chile	Kyrgyzstan	United Arab Emirates
Mauritius	China	Lebanon	United States
Mozambique	Colombia	Madagascar	Uruguay
Namibia	Costa Rica	Mali	Uzbekistan
Nepal	Croatia	Mexico	Venezuela
New Zealand	Cyprus	Morocco	Vietnam
Pakistan	Czech Republic	Netherlands	Yemen
Papua New Guinea	Denmark	Nicaragua	
Singapore	Djibouti	Niger	
South Africa	Dominican Republic	Nigeria	
Sri Lanka	Ecuador	Norway	
Tanzania	Egypt	Oman	
Thailand	El Salvador	Panama	
Trinidad and Tobago	Estonia	Paraguay	
Uganda	Ethiopia	Peru	
United Kingdom	Finland	Philippines	
Zambia	France	Poland	
Zimbabwe	Gabon	Portugal	