World Trade in Used Automobiles: A Gravity Analysis of Japanese and US Exports*

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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 USA, 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 classification codes: F13, F14, C20.

I. Introduction

The economic analysis of world trade in used durable goods began with the contribution of Sen (1962). This literature subsequently included Smith (1974, 1976), Pack (1978), Bond (1983) and Navaretti et al. (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, 2004) who analyzes the used automobile exports of the USA and by

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Clerides (2005) who analyzes the used automobile imports of Cyprus.[1] In the present paper, we are more comprehensive, analyzing the used automobile exports of both Japan and the USA. Specifically, we estimate a gravity model of these exports, using an original measure of used automobile protection in 121 importing countries of the world. We consider the used automobile exports of these 2 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 USA, with distance and protection levels being less significant and left-hand side driving patterns being a critical explanatory variable.[2]

II. 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 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, to 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.

Because 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 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

1. See also Panagariya (2000).
2. This refers to the side of the road the vehicle drives on.

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 reflect measures for Japanese exports. The ordinal measures can differ for US and Japanese exports because of special conditions and incentives accorded to one or the other exporter. Details of these modifications are available from the authors.

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

III. Gravity Model Specification

We model the used automobile exports of Japan and the USA in the year 2001 using two alternative gravity models.[3] The first model takes as its dependent

3. The gravity model has a very large literature going back to an initial burst of published literature appearing in the 1960s and early 1970s (e.g. Tinbergen, 1962; Linnenmann, 1966; Leamer and Stern, 1970, 1974; Aitken, 1973). For an important recent contribution, see Feenstra et al. (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).

variable the log of used automobile exports of Japan and the USA. 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 USA ($i = Japan, USA$) to the set of importing countries in our sample ($j = 1, \ldots, n$) using the following equation:

$$\begin{aligned} \ln e_{ij} = {} & \alpha_0 + \alpha_1 \ln gdp_j + \alpha_2 \ln pop_j \\ & + \alpha_3 \ln dist_{ij} + \alpha_4 protect_{ij} + \alpha_5 left_j \\ & + \alpha_6 europe_j + \varepsilon_{ij}. \end{aligned} \tag{1}$$

In this equation, e_{ij} is the exports of either Japan or the USA to importing country j as measured by the Japanese Customs and Tariff Bureau and the US International Trade Commission (United States International Trade Commission, 2006). The first right-hand side variable is the natural log of GDP in country j as measured by 2001 World Bank purchasing power parity data (World Bank, 2005).[4] 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.[5] Its expected sign is negative.

The fourth right-hand side variable is a dummy variable relating to the ordinal protection measure described in Section II. 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 USA and a positive sign for Japan.[6] 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 USA to the set of importing countries in our sample using the following equation:

$$\begin{aligned} \ln [prop_{ij}/(1 - prop_{ij})] = {} & \beta_0 + \beta_1 \ln (gdp_j/pop_j) \\ & + \beta_2 \ln dist_{ij} + \beta_3 protect_j + \beta_4 left_j + \beta_5 europe + \upsilon_{jj}. \end{aligned} \tag{2}$$

4. In some cases where World Bank data are not available (e.g. Taiwan), we use *US Central Intelligence Agency World Fact Book* estimates (United States Central Intelligence Agency, 2001, 2002).
5. See http://www.indo.com/distance/
6. In the Appendix, we provide a list of the left-hand side and right-hand side driving countries in our sample.

The left-hand side of Equation (2) is a transformed measure of $prop_{ij}$, the proportion of 2001 automobile exports from Japan or the USA to country j consisting of used automobiles. The left-hand side transforms $prop_{ij}$ as $\ln [prop_{ij}/(1 - prop_{ij})]$ 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 because of 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.[7] Therefore, we expect distance to increase the share of new automobiles and to 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 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).

IV. 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 USA, and its maximum exports is nearly three times that of the USA. This might indicate that Japan is more export oriented than the USA

7. 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 Borcherding 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.

Table 2 Descriptive statistics for Japanese and US automobile exports, 2001

Japanese exports	*N*	*Minimum*	*Maximum*	*Mean*	*Standard deviation*
New autos (units)	121	0	1 757 244	25 748	161 667
Used autos (units)	121	0	112 345	3176	11 691
GDP (US$m)	121	528	10 019 700	216 411	946 043
Population (thousand)	121	247	1 271 850	45 546	151 294
Distance (capital to capital, miles)	121	1303	11 544	6450	2180
Protect	121	0	3	1.058	1.150
Drive on left	121	0	1	0.27	0.45
Prop[a]	119	0	1	0.29	0.38
US exports	*N*	*Minimum*	*Maximum*	*Mean*	*Standard deviation*
New autos (units)	122	0	833 441	11 257	78 440
Used autos (units)	122	0	39 034	977	4143
GDP (US$m)	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	5418	2265
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 USA to country *j* consisting of used automobiles.

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 USA, 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 USA in that the mean distance to market (capital to capital) is approximately 1000 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 USA, with its great weight, in the US statistics. In general, Japan appears to be located at a significantly greater distance from its markets.

However, although both countries export to left-hand driving markets, a priori, left-hand side driving does appear to affect export volumes for Japan and the USA. Japan exports a mean of 3176 used automobiles per country on the whole, but a mean of 7600 to countries with left-hand side driving. For the USA, the average used auto export volume is 977, but for left-hand drive countries this declines to 399. More telling, however, is that the median exports of used

automobiles from Japan to left-hand drive countries is 1842, whereas for the USA 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.

V. Estimation Results

The estimation results for the gravity models of Equations (1) and (2) are presented in Table 3. This estimation uses the HC3 procedure for producing heteroskedasticy-consistent standard errors.[8] Columns 1 and 2 present results for Equation (1) (gross exports) as applied to the used automobile exports of the USA. 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, and 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 USA. 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, and 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 USA, 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 USA. The 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, therefore, indicate that the used automobile export behavior of Japan differs from that of the USA. More specifically, left-hand side driving is more important for Japan as a positive influence on export volumes than it is for the USA 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.

8. See White (1980), MacKinnon and White (1985) and Long and Ervin (2000).

Table 3 Gravity model results

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Variable/ measure	*US Gross exports*	*US Gross exports*	*US Export proportion*	*US Export proportion*	*Japan Gross exports*	*Japan Gross exports*	*Japan Export proportion*	*Japan Export proportion*
Constant	5.093	6.620	10.510**	11.286**	−10.991	−13.318	−5.507	−5.681
	(3.208)	(3.484)	(3.032)	(3.081)	(9.254)	(9.986)	(7.494)	(7.409)
ln gdp	0.933**	0.900**			0.645**	0.689**		
	(0.118)	(0.124)			(0.193)	(0.180)		
ln pop	−0.321*	−0.326*			−0.249	−0.205		
	(0.143)	(0.148)			(0.242)	(0.243)		
ln (gdp/pop)			−0.650**	−0.675**			−0.962**	−0.964**
			(0.098)	(0.101)			(0.205)	(0.205)
ln dist	−2.041**	−2.144**	−0.743*	−0.836*	0.275	0.359	1.056	1.079
	(0.360)	(0.353)	(0.356)	(0.359)	(0.753)	(0.812)	(0.772)	(0.757)
Left	−0.792*	−1.093*	0.100	−0.078	4.763**	4.599**	4.839**	4.733**
	(0.372)	(0.353)	(0.357)	(0.379)	(0.536)	(0.488)	(0.557)	(0.530)
Europe	−1.787**	−1.616**	−0.220	−0.074	−1.504	−1.768*	−0.548	−0.567
	(0.420)	(0.450)	(0.346)	(0.339)	(0.982)	(0.843)	(1.110)	(1.018)
Protect = 2,3	−1.220**		−0.932**		−0.229		−0.257	
	(0.360)		(0.322)		(0.844)		(0.735)	
Protect = 3		−1.110**		−0.751		−1.043		−0.440
		(0.533)		(0.497)		(0.942)		(0.914)
R^2	0.656	0.633	0.410	0.378	0.449	0.458	0.575	0.576
Observations	121	121	107	107	120	120	97	97

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

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 USA, 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.

VI. 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 USA, 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 a result, 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 might 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 is a cause for the variation in the factors influencing the two countries' export behavior.

The analysis in this paper uses 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 the present paper with panel data or with

data averaged over, say, a 3-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 the present 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.

Appendix
Left-hand and right-hand side drive countries in sample, 2001

Left-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	USA
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	

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