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The Impact of Trade Costs on Rare Earth Exports: A Stochastic Frontier Estimation Approach

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A Stochastic Frontier Estimation Approach**

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Abstract

The study develops a novel stochastic frontier modeling approach to the gravity equation for rare earth element (REE) trade between China and its trading partners between 2001 and 2009. The novelty lies in differentiating between 'behind the border' trade costs by China and the 'implicit beyond the border costs' of China's trading partners. Results indicate that the significance level of the independent variables change dramatically over the time period. While geographical distance matters for trade flows in both periods, the effect of income on trade flows is significantly attenuated, possibly capturing the negative effects of financial crises in the developed world. Second, the total export losses due to 'behind the border' trade costs almost tripled over the time period. Finally, looking at 'implicit beyond the border' trade costs, results show China gaining in some markets, although it is likely that some countries are substituting away from Chinese REE exports.

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NOMENCLATURE

EU	European Union
HREE	Sandia National Laboratories
LREE	light rare earths
REE	rare earth element
ROW	rest of the world
WTO	World Trade Organization

1 INTRODUCTION

“Rare earth elements” (REEs) is the common name for the fifteen elements of the lanthanide group, from lanthanum (atomic number 57) to lutetium (atomic number 71). Because REEs are chemically similar, typically they are found together in nature and are difficult to separate from one another. The term ‘rare earths’ is a misnomer, because the sources of rare earths are commonly found, with some elements more abundant than such other metals as silver and iron. The low level of production and availability to end users leads to the term ‘rare’ rather than natural scarcity of these minerals (Roskill Information Services, 2011).

REEs include light rare earths (LREEs)–lanthanum, cerium, praseodymium, neodymium, and samarium and heavy rare earths (HREEs)–europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, yttrium, and scandium. HREEs are typically rarer than LRREs and are generally more valuable. Several REEs have electronic, magnetic, catalytic, and optical properties that render them critically important for such emerging technologies as electric vehicles and next-generation wind turbines.

China produces 95% of the world’s REEs. Due to its lower cost of production, China collapsed the supply of rare earths coming from other mines from the rest of the world. In addition, China reduced the global supply of rare earths through various export restrictions, such as export taxes, export quotas, and restrictive licensing policies. In July 2010, China reduced export quotas by 40%, thereby prompting REE price increases outside China. Price increases were less inside China. Subsequent speculation, hoarding, and black market activity further increased REE prices. The United States (U.S.), the European Union (EU), and Japan filed simultaneous complaints against China related to exports of rare earths, tungsten, and molybdenum with the World Trade Organization (WTO). The materials covered by the complaints include REE ores, thorium ores and concentrates, REE oxides, carbonates, chlorides, fluorides and other compounds, and a variety of REE-containing magnetic powders and alloys (Lifton and Hatch, 2012).

The WTO complaints allege unfair treatment of foreign enterprises by Chinese export restrictions, discriminatory commercial rules within China, and lack of transparency in implementation of trade policies. China responded that such export restriction measures “… are necessary to protect human, animal or plant life or health” and are necessary to the conservation of exhaustible natural resources.” At present the case at the WTO continues, with no verdict for or against China with respect to restrictive trade practices (Lifton and Hatch, 2012).

Despite widespread media attention and political debate, very little quantitative analysis has been performed of the economic impact of China’s actions on REE-importing countries such as Japan and the U.S. or on China itself. To address this gap in knowledge, the authors quantify the impact of Chinese export restrictions on export flows and China’s export gains and losses due to changes in ‘behind the border’ constraints between 2001 and 2009.

This study modeled the effects of taxes on exports from China with a novel stochastic frontier estimation method. This method is superior over least-squares estimation of the log-linearized gravity model in the presence of heteroskedasticity[1] (Silva and Tenreyro, 2006) or in the case of observations with no trade between countries (Silva and Tenreyro, 2006; Westerlund and Wilhelmsson, 2006). The basic problem of log-linearization is that the presence of heteroskedasticity leads to inconsistent estimates,[2] because the expected value of the logarithm of a random variable depends on the higher order moments of its distribution. Thus if the errors are heteroskedastic, the transformed errors will be generally correlated with the covariates. An additional problem with log-linearization is that it is incompatible with the existence of zeros in the trade data, which leads to several unsatisfactory solutions, such as non-linear transformation of the dependent variable and truncation of the sample. To address such problems, Silva and Tenreyro (2006) propose a simple Poisson pseudo-maximum-likelihood estimation method and assess its performance using Monte Carlo simulations. They found that in the presence of heteroskedasticity, the standard methods severely bias the estimated coefficients, casting doubt on previous findings with regard to the log-linearized empirical model.

The central questions that must be answered are: (a) To which countries did China's rare earth exports decline because of increased 'behind the border' trade costs? and (b) With which countries did China's rare earth exports increase owing to decrease in 'implicit beyond the border costs' during the period of analysis? The distinction between 'behind the border' trade costs and 'implicit beyond the border costs' is important because the former refers to trade costs of the exporting country owing to improvement in trade infrastructure. In contrast, the latter trade costs refer to the removal of regulations to trade by the importing country. Both these trade costs have important influences on China's rare earth trade flows. Analyzing these trade costs is important to understanding whether China's export restrictions are leading to lower export flow from China to the rest of the world (ROW), and whether removal of regulations from China's partner countries is leading to higher imports from China.

In the next section, we provide an overview of the literature of the role of export taxes on export flows. We then develop an econometric specification that includes export taxes in a gravity trade model. This is different from other rare earths and trade studies, because it uses stochastic frontier estimation in a gravity trade modeling framework to estimate export losses owing to different components of exports–namely traditional demand factors, natural distances, 'explicit beyond the border costs' (such as export taxes and the real exchange rates), 'behind the border costs' (such as improvement in trade infrastructure in the exporting country), and 'implicit beyond the border' trade costs in the importing country, such as removing regulations to trade. We present the results of the estimation and the export losses incurred by China following higher export taxes in various markets. The conclusion provides a few implications of our results.

[1] In a classical linear model, when the scatter of the errors is different–that is, varying depending on the value of one or more of the independent variables–the error terms are *heteroskedastic*. Heteroskedasticity has serious consequences for the OLS estimator. Although the OLS estimator remains unbiased, the estimated SE is wrong. Because of this, confidence intervals and hypotheses tests are not reliable.

[2] In a standard gravity model of the form: $\ln T_{ij} = \ln \alpha_0 + \alpha_1 \ln Y_i + \alpha_2 \ln Y_j + \alpha_3 \ln D_{ij} + \ln \eta_{ij}$ estimating the parameters by ordinary least squares (OLS) assumes that $\ln \eta_{ij}$ is statistically independent of the regressors. Thus, if the variance of the error η_{ij} depends in the above equation on Y_i, Y_j, or D_{ij}, the expected value of $\ln \eta_{ij}$ will also depend on the regressors. This will violate the condition for consistency of the OLS estimates.

2 CHINESE EXPORT RESTRICTIONS IN RARE EARTHS: AN OVERVIEW OF THE CURRENT LITERATURE

Over the past decade, China has been imposing export restrictions on rare earth metals, oxides and alloy trade. These restrictions take various forms, including imposing export taxes, reducing export quotas, and prohibiting foreign companies from mining REEs in China unless they form joint ventures with Chinese companies (Morrison and Tang, 2012).

In what follows, we first discuss the rationale behind controlling exports of REEs and how REEs are traded globally and then discuss the various forms of export restrictions currently imposed by China to its trading partners.

2.1 Why Control Exports of REEs

Governments use export controls to promote their own domestic policies, such as developing value-added downstream industries, raising revenues, and controlling price volatility, as well as to achieve noneconomic goals, such as reducing environmental pollution and/or protecting animal, human, and plant health (Bonnariva et al. 2009). Export controls typically lower the domestic price of the restricted product by increasing supply and demand in the domestic market while prompting foreign consumers to search for new suppliers. But in the case of REEs, because there are no alternative suppliers, importers must inevitably look to decrease their REE consumption. In the short term, a net income transfer from the REE-importing countries to China will occur. Over the longer term, the Chinese REE export tax should lead to inefficiency in domestic downstream industries, because the REE price is artificially low. Foreign producers and consumers facing higher costs have an incentive to develop new technology or substitutes for the product to remain competitive (Korinek and Kim 2010).

Rare earths are sold as:

- Rare earth mineral concentrates, such as monazite concentrates from heavy mineral sand deposits;
- Mixed and separated rare earth compounds, such as oxides, carbonates, chlorides, nitrates, fluorides, etc.;
- Rare earth metals and specialist alloys, such as NdFeB and Sm-Co alloys used in magnet manufacturing; and
- Mischmetal – an alloy of REEs in their naturally occurring proportions.

The form of the rare earth is important. For example, 1 ton of rare earth carbonate contains approximately 400 to 500 kg of REEs, while 1 ton of mineral concentrate can contain only 200 kg of REEs.

The evolution of the Chinese competitive advantage in trade of rare earths can be traced back to the early 1990s, when high profit margins in the industry attracted new entrants. Competition increased, followed by production overcapacity and price-cutting, even as exports increased. Suppliers outside China were unable to compete with low Chinese prices and most of the world's mines were closed by the early 2000s (Morrison and Tang, 2012).

The percentage distribution of destinations of exports of rare earths from the Chinese mainland for 2012 is shown in Figure 2-1. Figure 2-1 shows that Japan accounts for 56% of total imports of rare earths from China, while the U.S. accounts for 14% of total imports. Five countries, namely Japan, the U.S., France, Hong Kong, and Germany account for almost 90% of total imports from China, which shows an extremely skewed pattern of rare earths trade.

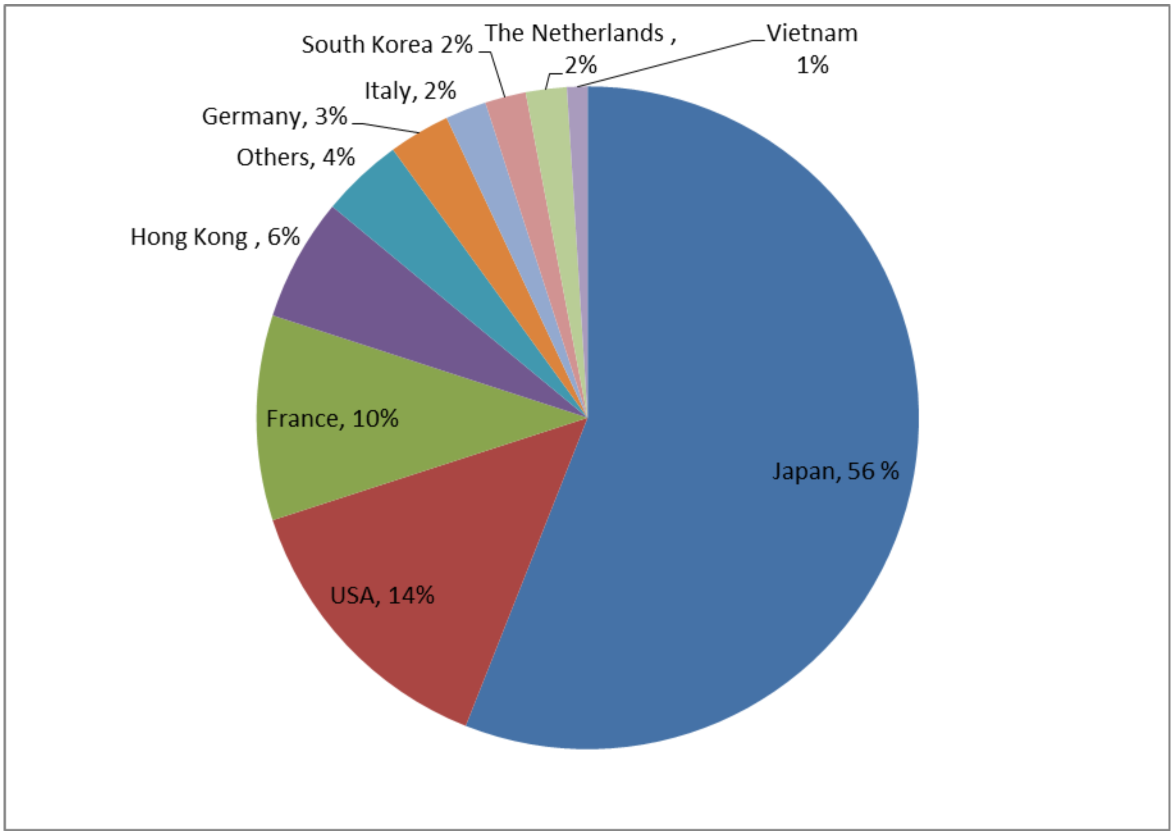

Figure 2-1. Destination of exports of REEs from China (2012)

2.2 Export Restrictions by China Over the Past Decade

The main control over global REE trade since 2000 has been Chinese trade policy. Data on Chinese rare earth exports[3] indicate that rare earth exports increased sharply from 1995 to 2003, but have sharply declined since then. The government of China is increasingly imposing export restrictions on raw materials including sawn timber, coke, oil, rare earths, antimony and its products, tungsten and its products, zinc ore, tin and its products, silver, indium, molybdenum, phosphate rocks, carbide, talc, magnesium, and bauxite, as well as a number of agricultural products (WTO, 2010). The 2010 WTO review[2] found that China's trade policies are inherently unfair, stating: "Whether intended or not, export restraints for whatever reason tend to reduce export volumes of the targeted products and divert supplies to the domestic market, leading to a downward pressure on the domestic prices of these products. The resulting gap between domestic prices and world prices constitutes implicit assistance to domestic downstream

[3] This data comes from Roskill Information Services through personal correspondence.

processors of the targeted products and thus provides them a competitive advantage. Insofar as China is a major supplier of such a product, export restraints may also shift the terms of trade in China's favour." China's export curtailing strategies include limiting export licenses, imposing higher taxes, and setting export quotas.

Export Licenses

Foreign companies are prohibited from mining REEs in China and prevented from smelting/separating REEs unless they form joint ventures with Chinese partners (Tse, 2011; Morrison and Tang, 2012). Sino-foreign joint ventures are permitted to export their products under a licensing system managed by the Chinese Ministry of Commerce (MOC).

The Chinese government gradually reduced the number of export licenses through tightening licensing rules and environmental regulations. In 2006, 47 Chinese domestic and 12 joint-venture rare earth companies received export licenses. In 2009, there were 23 domestic and 11 joint-venture licensees. These numbers were further reduced to 22 domestic and 10 joint-venture license holders in 2010 and, to 22 domestic and 9 joint-venture companies in 2011. During 2012, the Chinese government allocated first-round export quotas to 9 companies, with 17 other companies awaiting inspection results (Morrison and Tang, 2012). If these 17 companies meet environmental standards, the total count of companies with export permits would be 26, which is lower than 2011.

Export Taxes

On October 27th, 2006, the Chinese government announced that beginning on November 1, 2006, China would levy a 10% tax on many rare earth exports, excluding finished products such as phosphors and rare earth magnets. On May 21st, 2007, the government announced that the export tax would be a minimum of 10% (Roskill Information Services, 2011;Tse, 2011). This measure took effect on June 1st, 2007. The tax rates have since increased and now range from 15% to 25% and are applied to more rare earth products. In 2011, export taxes for ferroalloys containing more than 10% of REEs were subjected to a 25% export duty (Stewart et al., 2012). The tax on neodymium metal was increased from 15% to 25%.[3]

Export Quotas

Annual REE quotas are allocated to domestic firms and joint ventures with foreign investors. In 2006, 47 Chinese companies together with six foreign-controlled companies had export licenses. By 2011, the total number of companies with export licenses had been reduced to 37 companies (including foreign companies). Table 2-1 provides a breakdown of China's export quotas on rare earths.

Table 2-1. Total annual rare earth export quota granted to Chinese and joint ventures, 2005 to 2012 (in metric tons)

	2005	2006	2007	2008	2009	2010	2011	2012
Domestic	48,010	45,000	43,574	34,156	33,300	22,512	22,983	22,406
Joint venture	17,570	16,070	16,069	15,834	16,845	7,746	7,263	8,590
Total	65,580	61,070	59,643	49,990	50,145	30,258	30,246	30,996

Sources: Tse, China's rare earth industry, USGS Open File Report 2011-1042, Table 1; Technology Metals Research Data, Available at: http://www.techmetalsresearch.com/2012/12/the-first-round-of-chinese-rare-earth-export-quota-allocations-for-2013/

Because of Chinese export restrictions, several companies are substituting alternative materials for rare earths to reduce costs and dependence on Chinese supply. Toyota is developing a new REE-free induction motor for its electric and hybrid automobiles. General Electric (GE) is developing wind-turbine generators requiring less REEs (some offshore wind turbines contain as much as half a ton of REEs).[4]

As explained in the previous section, trade costs, such as export taxes, and quantitative restrictions, such as export quotas, influence the volume of export flows apart from relative factor abundance and comparative advantage in production. We model the effects of trade costs on export flows using a stochastic frontier estimation framework applied to a gravity trade model. The advantage of this approach is that changes in exports over time can be modeled as coming from five different sources: first, there are the traditional demand sources, such as per-capita income of the importing country or population. Second, there are factors such as natural distance that independently affect the volume of trade between any two countries. Third, there are "explicit beyond the border costs" that can be captured by export taxes and the real exchange rates. Fourth, there are "behind the border costs," such as improvement in trade and transport infrastructure, customs and port reforms, and investment in storage infrastructure that can improve export competitiveness. Finally, partner countries (importing countries) can also take reform measures, such as removing regulations on trade, thereby reducing the "implicit beyond the border" trade costs. In this study, the latter two effects were called the Khan-Kalirajan or KK effects.

[4] Bloomberg.com, Rare earths fall as Toyota develops alternatives: commodities, URL: http://www.bloomberg.com/news/2011-09-28/rare-earths-fall-as-toyota-develops-alternatives-commodities.html

3 METHODOLOGY

The static models of international trade do not accurately predict the effect of an export tax on export flows by a major exporter because in the static model, foreign consumers cannot buy from lower-priced supply sources when export taxes drive a wedge between export and domestic prices. In the exporter's domestic market, lower prices result in higher domestic consumption, while importers are likely to pay more for the product and decrease their consumption. In addition, static models do not capture REE substitution prompted by the difference between export and domestic prices. Stochastic frontier models allows us to better distinguish between (a) export losses arising due to "behind the border costs" in the exporting country; and (b) reduction in export losses that accrue owing to "implicit beyond the border" trade costs in the importing country. In this section, we first discuss the rare earth export growth decomposition into its individual components using a graphical analysis. This is followed by the model specification that is used for the empirical analysis in section 4.

3.1 Export Growth Decomposition into its Components

To quantify the effects of export taxes on export flows, we use a gravity model with stochastic frontier estimation (please see a detailed discussion of this estimation method in Appendix A)[5] for 2001 and 2009 to understand: (a) With which countries did China's REE exports decline owing to increase in 'behind the border' trade costs; and (b) With which countries did China's rare earth exports increase owing to decrease in 'implicit beyond the border costs.'

Figure 3-1 illustrates how changes in exports can be decomposed into the different components.

[5] The details of the stochastic frontier estimation model is given in Appendix A.

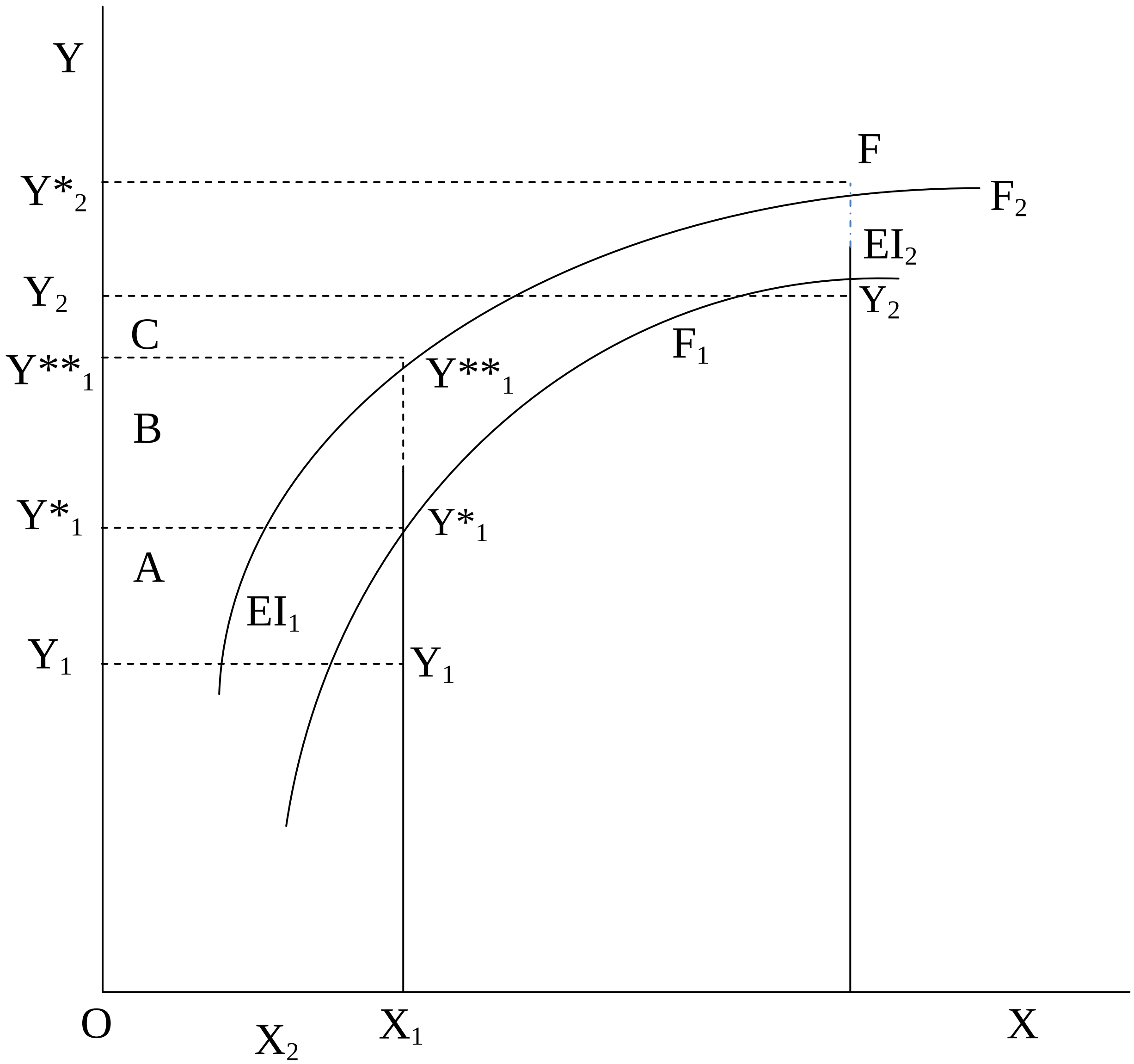

Figure 3-1. Rare earths export growth decomposition

In the above figure, the axes represent the potential and actual exports in two periods, namely period 1 and period 2. Let F_1 be the potential export frontier of home country in period 1 in the absence of 'behind the border' trade costs. The exports in the absence of 'behind the border' trade costs are Y_1^* in period 1, and can be called the potential exports. The actual export level is Y_1 and is less than Y_1^* due to institutional factors and infrastructural constraints in the home country. The gap $(Y_1^* - Y_1)$ or EI_1 is the export inefficiency owing to 'behind the border' trade costs that constrain exports from reaching full potential. However, the 'implicit beyond the border' trade costs that arise due to trade facilitation steps taken by the importing countries shift the export frontier from F_1 to F_2 in period 2. Thus, Y_2^* represents the potential exports without any 'behind the border' trade costs, while Y_2 denotes the actual exports in period 2. In other words, potential export growth due to reduction in 'implicit beyond the border' trade costs can be measured by the vertical distance between the frontier in period 1–i.e. F_1 (i.e. Y_1^*) –and the frontier in period 2, or F_2 (Y_1^{**}).

Thus the changes in realized exports can be decomposed into exports due to changes in demand, changes in 'explicit beyond the border' trade costs in importing country, change in 'implicit beyond the border' trade costs in importing countries, and changes in 'behind the border' trade costs in the home country:

$$\begin{aligned}\omega = Y_2 - Y_1 &= A + B + C \\ &= [Y_1^{*} - Y_1] + [Y_1^{**} - Y_1^{*}] + [Y_2 - Y_1^{**}] \\ &= [Y_1^{*} - Y_1] + [Y_1^{**} - Y_1^{*}] + [Y_2^{*} - Y_1^{**}] - [Y_2^{*} - Y_2] \\ &= \{[Y_1^{*} - Y_1] - [Y_2^{*} - Y_2]\} + [Y_1^{**} - Y_1^{*}] + [Y_2^{*} - Y_1^{**}]\end{aligned}$$

where

$[Y_1^{*} - Y_1] - [Y_2^{*} - Y_2]$ = Difference between export inefficiency in period 1 and period 2 arising from changes in 'behind the border' trade costs in the home country,

$[Y_1^{**} - Y_1^{*}]$ = Changes in exports due to trade facilitation steps taken by Chinese partner countries; also called "implicit beyond the border costs, " and

$[Y_2^{*} - Y_1^{**}]$ = Changes in exports due to the sum of the changes in the core determinants of trade like income per-capita, distance, and changes in "explicit beyond the border costs" such as export taxes and the real exchange rate.

3.2 Model Specification

The model then can be expressed as follows:

$$LnX_{ij} = \alpha + \beta_1 * Ln\,PGDP_j + \beta_2 * Ln\,Dist_j + \beta_3 * Ln(1 + T_{i,j}) + \beta_4 * LnRER_{i,j} - u_j \mid v_j$$

(1)

- where, α is the constant term in the regression equation, β_1 shows the marginal effect of per-capita GDP on bilateral exports ,and β_2 shows the marginal effect of bilateral geographical distance on bilateral exports.

Country *i* (in this case China) exports rare earths to a number of countries *j* (denoted by LnX_{ij}).

- The "explicit beyond the border costs" are captured by the export taxes ($T_{i,j}$) and the real exchange rate ($RER_{i,j}$).

- *Error Terms:* "Behind the border costs" (such as improving trade and transport infrastructure, customs and port procedure reforms and investment in storage infrastructure) are captured by the term u_j. (The assumption is made that u_j follows a truncated normal distribution.)

  The "implicit beyond the border costs" would be included in the normally distributed term v_j.

Equation (1) is estimated for each period separately using the computer software LIMDEP 10.0. Once the estimation results for the two periods are available, the change in China's exports to each partner country is computed based on variations in costs due to the five sources described previously.

4 DISCUSSION OF RESULTS

This section first defines the data that were collected for the empirical analysis. Next, it provides the main empirical results for the period 2001 and 2009 respectively, using maximum likelihood estimation method. The export losses based on 'behind the border' trade costs and the 'implicit beyond the border' trade costs are also computed for both periods. This analysis is performed to determine with which countries China is losing out in rare earths trade owing to its own export restrictions versus markets where China may be gaining owing to trade facilitation steps taken by Chinese partner countries.

4.1 Data

The exports of rare earths were taken from the various editions of the China Customs Statistics yearbook, while variables such as gross domestic product and population of importing countries were taken from the World Bank's World Development Indicators Database. The data on bilateral distance were from http://www.developing-trade.com/capacity-building. The data on export taxes of various rare earths were taken from Roskill Information Services and Tse (2011). Supplementary information was from the Metal Pages website at http://www.metal-pages.com/resources/chinese-export-tariffs/. The data on real exchange rate were taken from http://forex-markets.com/currency-converter.htm, and a yearly average exchange rate was computed for each importing country.

4.2 Analysis of Results

For empirical analysis, 24 countries were selected. The Chinese exports to these 24 countries were well above 90% of total exports of different rare earth oxides from China in 2009, and thus the sample is fairly representative. Taiwan was excluded from the list of countries for estimation and comparative static analysis, as information on the real effective exchange rate was missing for both years.

4.2.1 Export Losses Due to 'Behind the Border' Trade Costs

The estimation results for the cross-section estimation of the gravity model with the assumption of a composite error are given separately for 2001 and 2009 in Table 4-1. Equation (1) was estimated using 2001 and 2009 data separately with the assumption of a truncated normal distribution[6] and a full normal distribution respectively for the one-sided error term, u, representing the impact of 'behind the border' trade costs, while the statistical error term v represents the impact of "implicit beyond the border costs," and conventional statistical errors. These two effects are the aforementioned "KK effects." Because we are doing a one-sided test of $u = 0$ versus $u > 0$, Kodde and Palm tables must be used instead of the chi-square tests based on the likelihood ratio statistic.[7]

[6] Compared with the test of half-normal distribution, the LM test for truncated normal distribution utilizes only the third and fourth moments of the hypothesized truncated normal distribution of u and the conditional distribution of u conditional on ε. The estimated differences between the third and fourth moments of the conditional distribution given the samples and the corresponding moments of the specified unconditional distribution form the basis of the LM test.

[7] The steps required to perform the likelihood ratio tests are (a) estimate the unrestricted model (LogL(SF) with $u > 0$; (b) estimate the restricted model (LogL(LS) with $u = 0$; (c) compute LR = 2*[LogL(SF) - LogL(LS)); and (d) Reject the null hypothesis if LR > χ_R^2, where R denotes the number of restrictions in the model.

Table 4-1. Maximum likelihood estimates of the stochastic frontier gravity model — dependent variable (log of exports)

Independent Variables	Estimation for 2001	Estimation for 2009
Log of per capita GDP	1.008 (0.167)***	0.135 (0.37)
Log of distance	-0.335 (0.184)*	-1.015 (0.30)***
Log of export price	-0.027 (0.048)	-0.187 (0.172)
Log of real exchange rate	0.589 (1.079)	19.764 (6.253)***
Constant	-0.906 (5.233)	-74.57 (25.991)***
N	122	122
Model specification	χ^2_1 = 32.222 ***	χ^2_1 = 3.537 **
σ	2.851 ***	2.223***

Notes: a. *** and ** shows significance at the 1% and 5% respectively, while * shows significance at the 10% level. b. Export price variable means the ratio of export values to export quantity. c. We did not include export taxes as an explanatory variable in the Maximum Likelihood model as China did not impose export taxes prior to 2005.

All coefficients in the model are of the expected sign. However, the significance level of the independent variables changes dramatically from 2001 to 2009. While geographical distance matters in rare earth trade flows in both periods, the effects of per-capita GDP on export flows diminishes significantly from a one-to-one effect in 2001 to 0.13 in 2009 (see Appendix B for a discussion of this result). This result may indirectly capture the effects of financial crises in the developed world on per-capita GDP. For definitive answers we need a more detailed empirical specification, such a simultaneous equation model. However, the problem of using such a model is to find appropriate instruments that are well-correlated with the regressors but are not correlated with the error term. The choice of finding the right instruments is often difficult in practice and given the lack of consistent rare earths trade data, this modeling method was not used in the present study.

Higher export price has a negative effect on export flows but is not significant in both periods.[8] The real exchange rate effect is significant during 2009, but not in 2001. There is some multicollinearity between real exchange rate and export prices in the regression equation. It is likely that the real exchange rate may be picking up some of the variation of export prices on export flows. In addition, it is also plausible that China may be manipulating its currency to achieve trade advantage vis-à-vis other countries beyond its economic fundamentals. The successive revaluation in 2005 and again in 2010 through continuous intervention in foreign exchange markets has provided a competitive advantage over its trade competitors and trade

[8] Although export prices are not significant in the regressions, it does not necessarily imply that they are not important in export flows. For example, price setting producers (such as China in rare earths) can charge different factory prices across geographically segmented markets because of both price discrimination and pricing-to-market. Thus, if we can control for product-importer-period unobserved heterogeneity with fixed effects in the data, we may find distance decreases export prices to destinations that are richer than the exporter and increases export prices to the destinations to the poorer (Lugovskky and Skiba 2012). This fixed effect estimation was not feasible in the current study as end-use product categories of rare earths were not available.

partners (Arunachalaramanan and Golait 2011).[9] Overall, it appears from the regression results that there has been some amount of structural shifts in the Chinese economy with respect to rare earths trade, and the aggressive export control policies noted previously are confirmed.

Next, we compute the export losses that China incurred in each period due to the impact of 'behind the border' trade costs. This is calculated as the difference between the level of exports that would have happened in the absence of 'behind the border' trade costs ($u = 0$) and the actual exports that occurred in the presence of 'behind the border' trade costs ($u > 0$). The former exports are called "potential exports," while the latter are "realized exports."[10]

Table 4-2 provides China's export losses in rare earths due to 'behind the border constraints' for 2001 and 2009. The total export losses with all the trading partners due to 'behind the border' trade costs in 2001 turned out to be US $1.1 billion. The largest losses were observed with respect to exports to USA: neodymium, not intermixed or interalloyed (US $ 93.6 million); Japan: terbium oxide (US $26.5 million); Hong Kong: terbium oxide (US $23.42 million); Japan: cerium compounds, nes (US $19.42 million); and to Japan: cerium oxide (US $19.25 million).[11]

[9] C. Fred Bergsten is an American economist, author, and political adviser. He has previously served as Assistant for International Economic Affairs to Henry Kissinger within the National Security Council and as Assistant Secretary for International Affairs at the U.S. Department of the Treasury. In this context, it is important to quote him: "China's currency manipulation represents the largest protectionist measure maintained by any major economy since the Second World War. China has intervened in the foreign exchange markets by an average of $1 billion a day for the last five years, buying dollars to keep them expensive and selling renmimbi to keep them cheap, building a gigantic reserve of $2.5 trillion in the process. Largely as a result, the renmimbi is undervalued by at least 20% relative to economic fundamentals. The largest trading country in the world is therefore subsidizing all exports by at least 20% and imposing an additional tariff of at least 20% on all imports."

[10] These terminologies are borrowed from Khan and Kalirajan (2011).

[11] We provide the percentage distribution of export losses by countries due to 'behind the border' trade costs in Appendix C.

Table 4-2. China's export losses in rare earths due to 'behind the border constraints' (top 15 rare earths / countries) (in thousands of USD)

2001			2009		
Countries	**Rare Earths**	**Export Losses**	**Countries**	**Rare Earths**	**Export Losses**
Japan	Europium oxide	16,622.29	Germany	Yttrium oxide	45,428.05
Japan	Dysprosium not Intermixed or Interalloyed	17,534.36	Japan	Neodymium oxide	45,442.37
USA	Terbium oxide	17,888.60	Japan	Rare earth metals, scandium and yttrium, battery grade, intermixed/alloyed, nes	45,846.74
Japan	Rare earth oxides other than cerium, nes	18,438.15	Germany	Lanthanum oxide	48,139.40
Japan	Neodymium, not intermixed or interalloyed	18,465.14	Japan	Yttrium oxide	48,934.32
Japan	Yttrium oxide	18,492.76	Japan	Other rare earth metals, scandium and yttrium, not intermixed or interalloyed	49,120.64
Japan	Other rare earth metals, scandium and yttrium, not intermixed or interalloyed	18,584.81	Japan	Rare earth oxides other than cerium, nes	51,499.35
Japan	Neodymium oxide	18,743.13	Germany	Cerium oxide	53,057.72
Japan	Rare earth metals, scandium and yttrium, battery grade,	18,815.93	Japan	Lanthanum oxide	53,952.02

2001			2009		
Countries	Rare Earths	Export Losses	Countries	Rare Earths	Export Losses
	intermixed/alloyed,nes				
Japan	Lanthanum oxide	18,930.36	Japan	Cerium oxide	53,591.92
Japan	Cerium oxide	19,257.27	Japan	Cerium compounds, nes	62,064.96
Japan	Cerium compounds, nes	19,427.40	Hong Kong	Terbium oxide	64,951.16
Hong Kong	Terbium oxide	23,427.63	Hong Kong	Rare earth oxides other than cerium, nes	83,951.72
Japan	Terbium oxide	26,502.58	Hong Kong	Yttrium oxide	132,675.26
USA	Neodymium, not intermixed or interalloyed	93,577.60	Hong Kong	Lanthanum oxide	145,336.46

Source: Authors' own calculations based on equations (1) and (2).
nes denotes not especially specified.

Total export losses in 2009 almost tripled compared to the losses in 2001, amounting to US $3.1 billion. The largest losses were associated with Hong Kong, lanthanum oxide (US $145.33 million); Hong Kong, yttrium oxide (US $132.67 million); Hong Kong, rare earth oxides other than cerium, nes (US $83.95 million); Hong Kong, terbium oxide (US $64.95 million), and to Japan, cerium compounds, nes (US $62.06 million). This counterintuitive result of Hong Kong showing up as a major export destination is due to "re-export activities." Re-exports occur when products enter a customs territory from one country and are shipped to another country without undergoing any transformation. For example, if China reported rare earth exports to the U.S. of $1 billion (f.o.b valuation), while the U.S. reported $2.5 billion of rare earth imports from China (c.i.f valuation), it is possible that the additional $1.5 billion imports was from Hong Kong. Thus re-exports are more likely to occur in countries and regions with favorable geographical position in terms of competitive transportation and logistics costs. Although the harmonized information of re-exports statistics are generally not available across countries and is not reported in the COMTRADE database, related country-level statistics such as the national accounts and import matrices of input-output tables suggest that re-export and transshipment activities are significant in some countries, such as Hong Kong, China, and Singapore in Asia, and Belgium and The Netherlands in Europe (Zhu et al. 2011).[12] Overall, during 2009, we find that the major export losses in rare earths from China occur in the markets of Germany and Japan.

Next, we compute the export changes between 2001 and 2009 that resulted in reduction in 'behind the border' trade costs. The largest additional gain between 2001 and 2009 due to domestic reforms was through higher exports to Hong Kong (US $354.61 million), Germany (US $333.93 million), Japan (US $327.53 million), The Netherlands (US $283.05 million), and Korea (US $153.52 million). The largest increases in export losses between 2001 and 2009 were identified with respect to Australia (US $8.43 million), Norway (US $5.11 million), and Canada (US $3.46 million). Overall, of the 24 countries in the sample, China has made export gains for 19 countries. The pattern of gains and losses indicate that China could enjoy additional gains in the export markets to stable countries such as Australia and Canada (the percentage of export losses due to 'behind the border' trade costs is given in Appendix C).

The above results also indicate that in general foreign trade has been the major vehicle of economic growth, contributing to over 50% of China's GDP since 2002. After being fully integrated on November 11, 2001, to the WTO as the 143rd member, China's trade grew exponentially, with imports and exports both crossing the $1 trillion mark in 2008 (WTO, 2010). In 2009, owing to the worldwide recession, China's exports declined by 16%, while imports fell by 11% due to sluggish demand both at home and abroad. At the same time, because of the export restriction policies described in section 2, Chinese exports also became the major target of worldwide protectionist measures.

China's response to the financial crisis was a stimulus package of 4 trillion renminbi (US $570 billion) during 2008. This stimulus package was targeted at domestic programs, such as low-income housing, rural infrastructure, other infrastructures such as water, transportation, and electricity, technological innovation, the environment, and disaster rebuilding (Naughton, 2009). Simultaneously, China sought to expand its trade with developing and emerging market countries further through signing bilateral and free trade agreements (FTAs) with Association of

[12] Complete information of re-exports, i.e., the origin and destination countries by products, is not publicly available at present.

South East Asian Nations (ASEAN) countries in November 2002. Since 2002 China has signed nine additional FTAs and economic partnership arrangements (EPAs) with Singapore, Pakistan, New Zealand, Chile, Peru, Costa Rica, Hong Kong, Macao, and, most recently, Taiwan. Overall, China's existing and proposed FTAs cover 28 economies in five continents (Li, 2012).

With the onset of the fiscal stimulus and trade diversification policies during 2008, China's trade has rebounded with new partners during 2010 with countries such as Hong Kong, India, and Korea, while the export market share have remained constant with traditional partners, such as Japan, the EU, and the U.S. (Li, 2012).

4.2.2 Export Losses Due to 'Implicit Beyond the Border' Trade Costs

Trade facilitation measures taken by importing countries result in reduction in the impact of 'implicit beyond the border' trade costs (Khan and Kalirajan, 2011). This is the v term in equation (1) and shows the potential exports in the absence of 'behind the border' trade costs in period 1, i.e., the year 2001, and the level of China's potential exports in the absence of 'behind the border' trade costs in period 1 had the second period export environment of reduced 'implicit beyond the border' trade costs existed in the first period.

Table 4-3 suggests that China is gaining in foreign markets such as Italy (cerium oxide), Germany (yttrium oxide, lanthanum oxide, and cerium oxide), and Japan (cerium oxide and cerium compounds, nes) owing to reduction in "implicit beyond the border" trade costs over the period 2001 to 2009. At the same time, some countries were possibly substituting away from Chinese exports of rare earths by either substituting other materials for rare earths or through opening up new mines. For example, the losses of China in the export markets of the U.S in neodymium, not intermixed or interalloyed, and terbium oxide; Japan in terbium oxide; Norway in rare earth oxides other than cerium, nes; Australia in rare earth metals, scandium and yttrium battery grade, intermixed/alloyed, nes, and cerium compounds, nes; and Canada in rare earth oxides other than cerium, nes are significant.

Table 4-3. Top 10 countries/rare earths with respect to China's export gains and losses due to changes in 'behind the border constraints' between 2001 and 2009 (in thousands of USD)

Gains			Losses		
Countries	**Rare Earths**	**Change**	**Countries**	**Rare Earths**	**Change**
Italy	Cerium oxide	35,820.78	USA	Neodymium, not intermixed or interalloyed	-69,912.74
Germany	Yttrium oxide	37,572.58	Norway	Rare earth oxides other than cerium, nes	-5,116.73
Germany	Lanthanum oxide	39,927.72	USA	Terbium oxide	-4,778.10
Japan	Cerium oxide	40,334.64	Australia	Rare earth metals, scandium and yttrium, battery grade, intermixed/alloyed, nes	-4,227.06
Hong Kong	Terbium oxide	41,523.52	Australia	Cerium compounds, nes	-4,208.13
Japan	Cerium compounds, nes	42,637.55	Japan	Terbium oxide	-3,609.05
Germany	Cerium oxide	45,299.60	Canada	Rare earth oxides other than cerium, nes	-3,464.44
Hong Kong	Rare earth oxides other than cerium, nes	67,958.86	UK	Dysprosium not Intermixed or Interalloyed	-1,460.98
Hong Kong	Yttrium oxide	116,383.60	Mexico	Rare earth oxides other than cerium, nes	-432.56
Hong Kong	Lanthanum oxide	128,747.2	Brazil	Cerium oxide	-221.13

Note: Positive sign indicates reduction in losses/additional exports during the two periods; negative sign shows increase in losses/reduction in exports during the two periods.
nes denotes not especially specified.

For example, several countries, including the U.S., are taking steps to mitigate the supply shortages of rare earths after almost 20 years.

- In late 2011, U.S.-based Molycorp Inc. restarted its rare earth mineral production at its Mountain Pass mine in California (closed in 2002) and is currently expanding its operations.

- In February 2012, Molycorp Inc. announced the start-up of the new Project Phoenix rare earth manufacturing facility at its Mountain Pass mine. The facility takes REE ore mined on the site and feeds it into a new crushing facility. Mechanical completion of the initial cracking facility has been achieved and feedstock from stockpiled material has been fed into the system. Other operations that will be brought to this facility in the coming months include milling and mineral extraction, expanded cracking, impurities removal, rare earth oxide separations, product finishing, etc. (Canadian Chamber of Commerce, 2012).

- The European Commission plans to invest 17 million Euros (US $ 21.7 million) for research into substitutes for rare earth minerals and also to improve technologies for mining more deeply underground; the Commission estimates the value of unexploited rare earth minerals at depths of 500-1,000 meters at 100 billion Euros (US $127 billion) (Dempsey, 2010).

- The Japanese government (the world's biggest importer of rare earths as depicted in Figure 1) is developing a national strategy on rare earths with emphasis on increasing stockpiles, recycling from discarded electronics, and finding new sources from Mongolia and Vietnam (UNEP, 2011).

- In addition, researchers from the University of Tokyo, the Japan agency for Marine-Earth Science and Technology, and the Tokyo Institute of Technology have discovered REEs in some places of the ocean floor of the Pacific, the stock of which could be 1,000 times the amount available on land surfaces (Kato et al., 2011).

- In Western Australia, Lynas Corporation's Mt. Weld mine will provide a new source of supply as production came online during the second quarter of 2012. Lynas is also constructing a rare earths processing plant in Malaysia that will have the capacity to meet one-fifth of world demand (Canadian Chamber of Commerce, 2012).

- In Canada, Great Western Minerals Group Ltd's Hoidas Lake project, located in northern Saskatchewan, has one of the highest proportions of neodymium present in any known rare earth deposit. These deposits are important for the permanent magnet industry. The company is working on designing an optimal concentration/leaching process with the goal of starting production in 2015-16.

- Similarly, the Quest Rare Earth Mineral Ltd. is exploring several rare earth projects in the Strange Lake and Misery Lake areas of northeastern Quebec in Canada. These mineral deposits are amenable to a low-cost open pit mine with the potential to become a major source of stable supply of separated and refined rare earths.

As pointed out by Hensel (2011), the strategies of Japan and the U.S. in responding to the increase in rare earth prices have been quite different. While Japanese companies and the Japanese government focused on recycling and finding alternatives to REEs, the focus of the U.S. has been to re-open Molycorp. This difference in responses is because the U.S. has a relatively smaller manufacturing base for computers and hybrid cars compared to Japan; thus U.S. firms were less impacted by export quotas and export restrictions than Japanese companies.

5 CONCLUSIONS

China produces 95% of the total rare earth supply. Due to its lower cost of production, China collapsed the supply of rare earths from the rest of the world. In addition, China reduced the effective supply of rare earths through restrictive export policies, such as export taxes, export quotas, and export licensing. The result of these export restrictions led to export market losses for China but a high price differential between export prices and domestic prices of rare earths.

Thus in order to estimate these export losses, we propose a novel stochastic frontier modeling approach to the gravity equation estimation for rare earths trade between China and its trading partners. The approach differentiates 'behind the border' trade costs, such as improving trade and transport infrastructure, customs and port procedures and other infrastructure investments for China, and the 'implicit beyond the border costs,' such as trade facilitation reforms by China's trading partners. This distinction is important as trade costs can have important influences in the volume of exports apart from relative factor abundance and comparative advantage in production.

In this study, we ask the following questions: (a) To which countries did China's rare earth exports decline because of increased 'behind the border' trade costs?; and (b) With which countries did China's rare earth exports increase owing to decrease in 'implicit beyond the border costs' during the period of analysis?

5.1 Main Results

Our results indicate that the significance level of the independent variables change dramatically over the time period. While geographical distance matters in export flows in both periods, the effect of per-capita GDP is attenuated from a one-to-one effect to 0.13. This result may indirectly capture the effects of the financial crises in the developed world. The real exchange rate effect is significant in 2009 but not in 2001. This result may indicate two things:

1. It may be picking up some of the variation of export prices on export flows and

2. Successive revaluation in 2005 and again in 2010 through continuous intervention in foreign exchange markets may have given China an unfair competitive advantage over its trade partners.

When modeling 'behind the border' trade costs, we find that the total export losses during 2001 turned out to be US $1.1 billion. The largest losses were observed with respect to exports to the U.S. and Japan. The total export losses in 2009 almost tripled in 2009 to US $3.1 billion. During this period, the major export losses occurred in the markets of Germany and Japan.

Our calculation of 'implicit beyond the border' trade costs indicates that China is gaining in markets such as Italy (cerium oxide), Germany (yttrium oxide, lanthanum oxide, and cerium oxide), and Japan (cerium oxide and cerium compounds, nes) during this time period. Nevertheless, it is likely that some countries are possibly substituting away from Chinese exports of rare earths by either substituting other materials for rare earths or through opening new mines. These markets include the U.S. (neodymium, not intermixed or interalloyed, and terbium oxide), Canada (rare earth oxides other than cerium, nes), Australia (rare earth metals, scandium and yttrium, battery grade, intermixed /alloyed, nes), and Japan (terbium oxide).

5.2 Implications

The main insights provided by the model is the distinction between 'behind the border' trade costs and the 'implicit beyond the border' trade costs for China and its trading partners. Our results suggest that export restrictions such as export taxes on rare earths may not be beneficial to the Chinese economy due to the significant increase in losses in 'behind the border' trade costs between 2001 and 2009. In addition, we also find that for some country/rare earths combinations, China is losing in several markets owing to 'implicit beyond the border' trade costs. This latter result may be due either to countries opening up new mines or substituting other materials for rare earth minerals. Thus it is possible that although in the short-run China will remain a dominant player in the rare earths industry, in the long-run, this dynamic may change.

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APPENDIX A: FORMULATION OF THE STOCHASTIC FRONTIER MODEL: A TECHNICAL DIGRESSION

The stochastic production frontier model was originally motivated by the idea that deviations from the production "frontier" may not be entirely under the control of the production unit under study (Aigner et al., 1977; Batesse and Corra, 1977). These models allow for technical inefficiency, but they also acknowledge that random shock outside the control of producers can affect output. They account for measurement error and other factors, such as effects of weather, luck, and the like, on the value of the output variable, together with the combined effects of the unspecified input variables in the production function.

An appropriate formulation of a stochastic frontier model in terms of a general production for the j^{th} production unit can be represented by:

$$y_j = f(x_j, \beta) + v_j - u_j = f(x_j, \beta) + \varepsilon_j \quad \text{(A-1)}$$

where, v_j denotes the two-sided "noise" component, and u_j denotes the non-negative technical inefficiency component of the error term. The noise component v_j is assumed to be independently and identically distributed (iid) and symmetric, distributed independently of u_j. Thus, the error term $\varepsilon_j = v_j - u_j$ is not symmetric, because $u_j \geq 0$.

Assuming that v_j and u_j are distributed independently of x_j, estimation of (1) by ordinary least squares (OLS) provides consistent estimates of the parameters except α, as $E(\varepsilon_j) = -E(u_j) \leq 0$. In addition, OLS does not provide estimates of producer-specific technical efficiency. The main objective of the estimation is to determine producer-specific technical inefficiency u_j.[13] This requires distributional assumptions on the two error components and thus requires the normal half-normal stochastic frontier model.

A.1 The Normal Half-normal Stochastic Frontier Model

We make the following distributional assumptions:

(i) $v_j \sim iid\ N(0,\sigma_v^2)$
(ii) $u_j \sim iid\ N^+(0, \sigma_u^2)$ *i.e.* non-negative half-normal
(iii) v_j and u_j are distributed independently of each other, and of the regressors.

The density function of $u \geq 0$ is given by:

$$f(u) = \frac{2}{\sqrt{2\pi}\,\sigma_u} exp\left\{-\frac{u^2}{2\sigma_u^2}\right\} \quad \text{(A-2)}$$

Similarly, the density function of v is:

$$f(v) = \frac{2}{2\pi\sigma_v} exp\left\{-\frac{v^2}{2\sigma_v^2}\right\} \quad \text{(A-3)}$$

[13] To achieve this objective in our framework, it is important that the separate estimates of "the implicit beyond the border costs," v_j, and technical inefficiency, u_j, are extracted for each countries that China exports rare earths.

Given the independence assumption, the joint density function of *u* and *v* is the product of individual density functions, given by:

$$f(u,v) = \frac{2}{2\pi\sigma_u\sigma_v} exp\left\{-\frac{u^2}{2\sigma_u^2} - \frac{v^2}{2\sigma_v^2}\right\} \quad \text{(A-4)}$$

Because $= v - u$, the joint density function of *u* and ε is given by

$$f(u,\varepsilon) = \frac{2}{\sqrt{2\pi}\sigma_u\sigma_v} exp\left\{-\frac{u^2}{2\sigma_u^2} - \frac{(\varepsilon+u)^2}{2\sigma_v^2}\right\} \quad \text{(A-5)}$$

The marginal density function of ε is obtained by integrating u out of $f(u,\varepsilon)$ and this yields

$$f(\varepsilon) = \int_0^\infty f(u,\varepsilon)du$$
$$= \frac{2}{\sqrt{2\pi}\ \sigma}\left[1 - \emptyset\left(\frac{\varepsilon\lambda}{\sigma}\right)\right].\exp\left\{-\frac{\varepsilon^2}{2\sigma^2}\right\} \quad \text{(A-6)}$$
$$= \frac{2}{\sigma}\varphi\left(\frac{\varepsilon}{\sigma}\right)\emptyset\left(-\frac{\varepsilon\lambda}{\sigma}\right)$$

where, $\sigma = \sqrt{(\sigma_u^2 + \sigma_v^2)}$, $\lambda = {}^{\sigma_u}/_{\sigma_v}$, and $\varphi(.)$ and $\emptyset(.)$ are the standard normal density and cumulative distribution functions.

The marginal density function $f(\varepsilon)$ is asymmetrically distributed, with mean and variance given by:

$$E(\varepsilon) = -E(u) = -\sigma_u\sqrt{\frac{2}{\pi}}$$
$$V(\varepsilon) = \frac{\pi-2}{\pi}\sigma_u^2 + \sigma_v^2 \quad \text{(A-7)}$$

The normal half-normal distribution contains two parameters, σ_u and σ_v. Because $\sigma_u > 0$ and the mode of the distribution is negative, the normal half-normal distribution is negatively skewed.

The log likelihood function[14] for a sample of N countries that China exports to is given by:

$$\ln L = -(N/2)(\ln 2\pi + \ln\sigma^2) + \Sigma[\ln\emptyset\left({}^{-\varepsilon_i\lambda}/_{\sigma}\right) - \frac{1}{2}({}^{\varepsilon_i}/_{\sigma})^2 \quad \text{(A-8)}$$

[14] The first-order conditions of the log likelihood maximization provide an estimation of the frontier parameters in equation (A-9). These estimates are consistent as $N \rightarrow +\infty$.

The estimation of the inefficiency term u_j is of interest to us. Because $E(u_j)$ is a summary measure of the distribution, it is difficult to decompose the individual residuals into the two components and estimate the technical inefficiency of each individual country to which China exports. A solution to this problem can be obtained from the conditional distribution of u_j given ε_j .

Jondrow et al. (1982) showed that if $u_j \sim N^+(0, \sigma_u^2)$, the conditional distribution of u given ε is truncated at zero and is given as follows:

$$f(u|\varepsilon) = \frac{f(u,\varepsilon)}{f(\varepsilon)}$$

$$= \frac{1}{\sqrt{2\pi}\,\sigma_*} e^{exp\left\{-\frac{(u-\mu_*)^2}{2\sigma_*^2}\right\}} \Big/ \left[1 - \phi\left(-\mu_*/\sigma_*\right)\right] \quad \text{(A-9)}$$

where, $\mu_* = -\varepsilon\sigma_u^2/\sigma^2$ and $\sigma_*^2 = \sigma_u^2\sigma_v^2/\sigma^2$.

As $f(u|\varepsilon)$ is distributed as $N^+(\mu_*, \sigma_*^2)$, the mean of this distribution can serve as a point estimator of u_j. This is given as follows:

$$(u_j|\varepsilon_j) = \mu_{*i} + \sigma_*\left[\frac{\varphi(-\frac{\mu_{*j}}{\sigma_*})}{1 - \phi\left(-\mu_{*j}/\sigma_*\right)}\right]$$

$$= \sigma_*\left[\frac{\varphi\left(\varepsilon_j\lambda/\sigma\right)}{1-\phi\left(\varepsilon_j\lambda/\sigma\right)} - \left(\frac{\varepsilon_j\lambda}{\sigma}\right)\right] \quad \text{(A-10)}$$

From (A-10), estimates of u_j can be obtained as

$$TE_j = \exp(-\hat{u}_j) = \exp\{-E((u_j|\varepsilon_j)\} \quad \text{(A-11)}$$

APPENDIX B: RELATIONSHIP OF RARE EARTHS EXPORTS AND PER-CAPITA GROSS DOMESTIC PRODUCT DURING 2001 AND 2009

This appendix provides the relationship between log of exports plotted against log of per-capita gross domestic product (GDP) for two time periods: 2001 and 2009. This relationship is based on the maximum likelihood estimates of Table 4-1.

The relationship depicted below shows that log of exports have a one-to-one effect with log of per-capita GDP during 2001 (Figure B-1). However, this relationship significantly diminished during 2009 as depicted in Figure B-2.

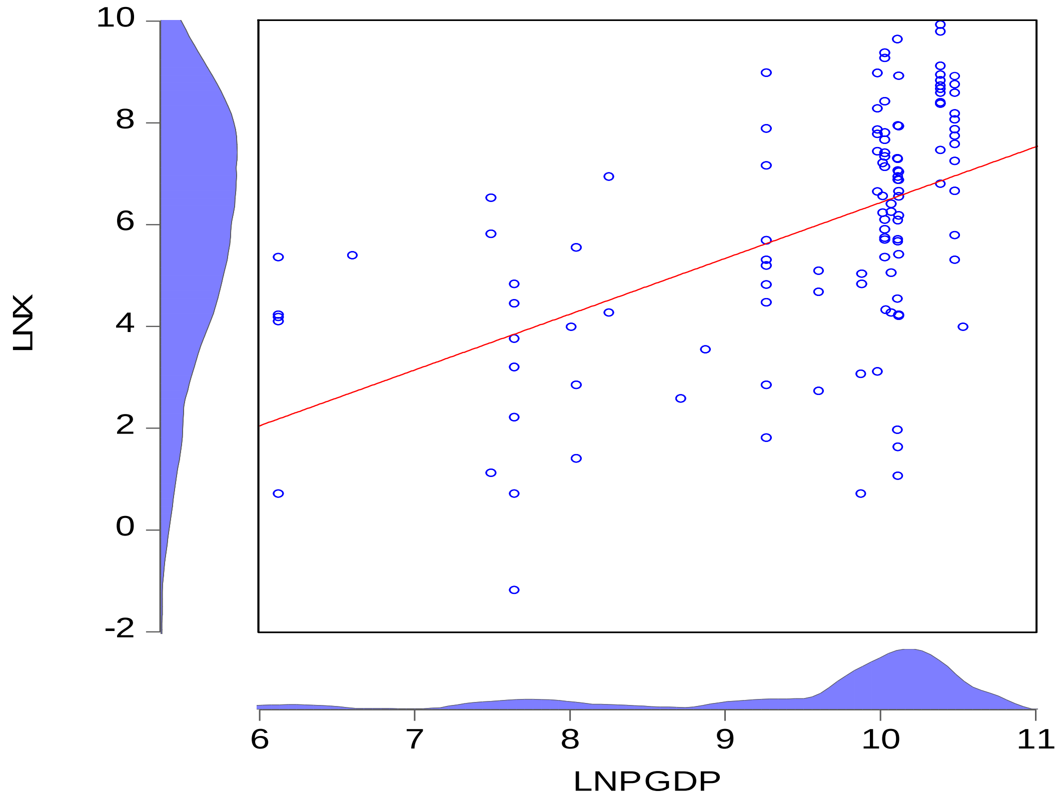

Figure B-0-1. Log of exports plotted against log of per-capita GDP (2001)

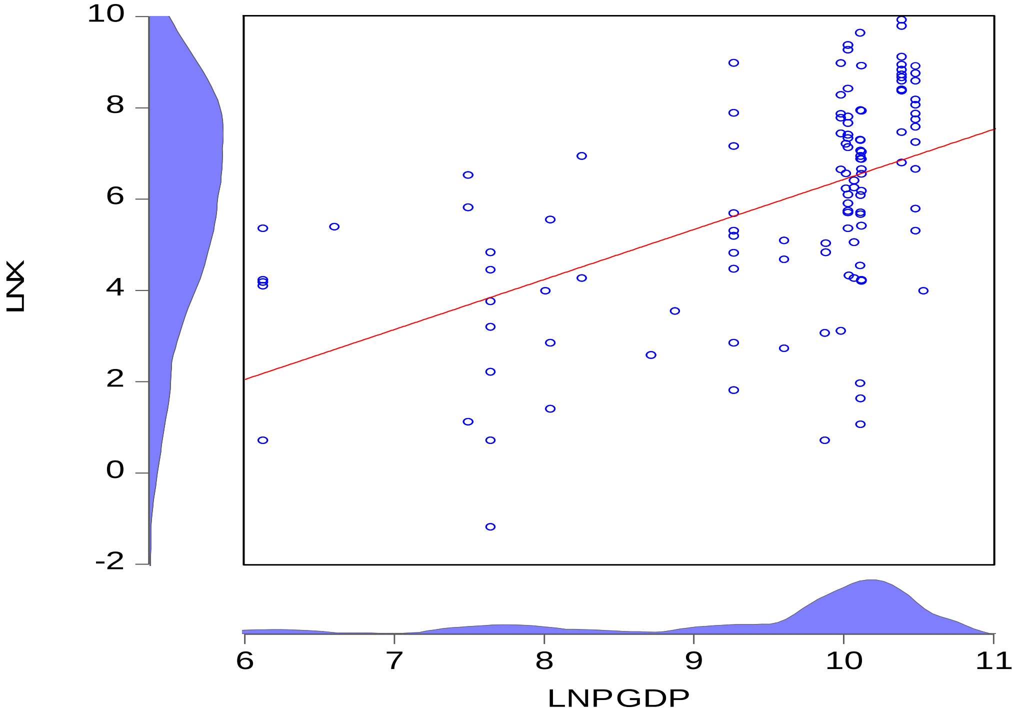

Figure B-2. Log of exports plotted against log of per-capita GDP (2009)

APPENDIX C: PERCENTAGE DISTRIBUTION OF EXPORT LOSSES FOR MAJOR PARTNERS OF CHINA DUE TO BEHIND THE BORDER TRADE COSTS DURING 2001 AND 2009

Based on Table 4-2 (above), we also compute the percentage of rare earth export losses that China incurs with its trading partners during 2001 and 2009 owing to 'behind the border' trade costs. We undertake this exercise to demonstrate which rare earth export markets China lost during 2001 and 2009 respectively. As evident from the table below during 2001, the major losses were incurred for Japan, U.S., and Germany. In 2009 however, the major export markets losses were incurred Japan, Germany, and Hong Kong. This may suggest that during the latter period, there was lot of re-export activities going on through Hong Kong export markets.

Table C-1. China's export losses in rare earths due to 'behind the border constraints' (top 15 rare earths / countries) (in thousands of USD)

Countries	% of export loss (2001)	% of export loss (2009)
Argentina	0.289	0.353
Australia	0.967	0.072
Austria	3.082	3.478
Belgium	2.068	2.858
Brazil	0.173	0.049
Canada	0.501	0.066
France	4.725	6.562
Germany	9.662	14.208
Hong Kong	6.548	13.765
India	0.087	0.408
Indonesia	0.021	0.053
Italy	1.216	2.493
Japan	23.018	18.756
Korea	6.731	7.347
Malaysia	0.304	0.625
Mexico	0.186	0.052
Netherlands	7.678	11.86
Norway	1.228	0.272

Countries	% of export loss (2001)	% of export loss (2009)
Russia	0.413	0.544
Spain	1.304	2.566
Thailand	0.207	0.859
Turkey	0.078	0.056
UK	7.874	3.894
US	21.131	8.79

Source: Authors’ own calculations based on equation (1)

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