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ANTI-COMPARATIVE ADVANTAGE: A PUZZLE IN U.S.-CHINA BILATERAL TRADE

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Anti-Comparative Advantage:
A Puzzle in U.S.-China Bilateral Trade*

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April 2015

Abstract

From 1992 to 2011, the total trade volume between the U.S. and China increased by 25 times, and China's share in U.S. total imports increased from 5% to 20%. However, the U.S.'s share in China's total imports **dropped** from 11% to 8% in the same period. In the major categories of U.S. exports to China, **Waste & Scrap** increased from 744 million dollars in 2000 to 7,562 million dollars in 2008, rising 916% times and becoming the No.1 product that the U.S exports to China. It is important to understand what explains these structural changes, and to ask whether the principle of comparative advantage determines the structure of U.S.-China bilateral trade. Interestingly, we find an "Anti-Comparative Advantage" puzzle: the U.S. exports less to China in sectors where it has greater comparative advantage, while China exports more to the U.S. in its sectors with greater comparative advantage. To further study this issue, we extend Eaton-Kortum model of bilateral trade to multiple sectors and test it empirically using US and China trade data. We find that after controlling for the importer's demand, trade costs and factor intensities, etc., comparative advantage cannot explain U.S.-China bilateral trade flows. The puzzle survives various robustness checks.

1.   Introduction

From 1992 to 2011, total trade volume between the U.S. and China increased by 25 times, and China's share in U.S. total imports increased from 5% to 20%. By contrast, the U.S.'s share in China's total imports shrank from 11% in 1992 to 8% in 2011. In the same period, the U.S.'s trade deficit with China increased by more than 150 times, from 1.45 billion USD to 235 billion. Figure 1 is from page 77 of the "2009 Report to Congress of the U.S.-China Economic and Security Review Commission", which reports major U.S.'s exports to China between 2000 and 2008.[1]

While the U.S.'s share in China's total imports declined, the total volume of U.S.'s exports to China increased from 16,253 million USD in 2000 to 71,457 million USD in 2008, rising by 339%. Probably most surprisingly, the top one product that the U.S. exports to China is Waste & Scrap, above Semiconductors & Other Electronic Components, Oilseeds & Grains, and Aerospace Products & Parts. Exports of Waste & Scrap from the U.S. to China increased from 744 million dollars in 2000 to 7,562 million dollars in 2008, rising by 916% times. Among them, Copper Waste and Scrap, and Aluminum Waste and Scrap accounted for 5% and 4% of total U.S. exports to China in 2011, respectively. U.S.'s exports to China as a share of total U.S. exports to the world in Copper Waste and Scrap was only 8% in 1996, but increased to 69% in 2011.[2]

This paper aims to understand what determines the structure of U.S.-China bilateral trade. In particular, we want to investigate the role of comparative advantage. Our paper is related to the recent empirical literature testing the Ricardian theory of comparative advantage. The Ricardian model predicts that countries should produce and export relatively more in industries that are relatively more productive. Costinot, Donaldson, and Komunjer (2012) and Costinot and Donaldson (2012) apply the Eaton and Kortum model (2002) to multiple-country empirical tests and show that Ricardo's ideas are supported by the data. In this paper we extend Eaton-Kortum's model to multiple sectors in bilateral trade and empirically test the role of Ricardian comparative advantage in determining the U.S.-China trade structure. In contrast to Costinot, Donaldson, and Komunjer (2012) who derive a "difference-in-difference" form of an empirical equation based on the theory, we derive a more straightforward "difference" form of the Ricardian test: the difference between the log of country i's exports to country n and the log of country n's consumption of its own product is explained by the log of relative productivities and relative unit costs between the two countries. Interestingly, we observe a puzzling pattern in U.S.-China bilateral trade: we find that the U.S. exports *less* to China in sectors where it has *greater* comparative advantage (measured by relative labor productivity or relative TFP between U.S. and China). We call such an abnormal data pattern the "Anti-Comparative Advantage Puzzle". In contrast, the cross-sector pattern of China's exports to the U.S. is consistent with Ricardo's idea. These results hold after controlling for demand size, trade costs and production costs, and when we exclude metal products and processing trade. Regressions of multilateral trade

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[1]   Readers are guided to the website: http://www.dtic.mil/dtic/tr/fulltext/u2/a520210.pdf

[2]   See Table 1 on page 5.

flows further indicate that China is an outlier in the U.S.'s global exports.

An emerging literature has studied the pattern of China's export, and its influence on developed countries, especially the U.S.[3] China's increasing globalization has not only brought a flood of cheap products to consumers in advanced economies, but also raised concerns about the impact on global imbalances (Krugman, 2010) and labor welfare (Autor, et al., 2012)[4]. Most studies focus on China's export, rather than other countries' exports to China or their bilateral trade structure. One exception is Hammer, Koopman, and Martinez (2009), which documents how exports of Advanced Technology Products (ATP) from the U.S. to China have expanded rapidly in recent years, and become increasingly concentrated in electronic products. This reveals the integration of both the U.S. and China into the global supply chain of IT products. Our paper contributes to the literature with a comprehensive examination of the bilateral trade structure between China and the US.

The anti-comparative advantage pattern in U.S. exports has been observed by other studies. Notably, Berger et al. (2012) explored the declassified CIA documents to examine whether U.S. power was used to influence countries' trade decisions during the Cold War. Controlling for bilateral trade costs, political ideology, and the supply of U.S. loans and grants, they found that CIA interventions have increased imports of foreign countries from the U.S. Moreover, the increase concentrated in industries where the U.S. had comparative disadvantage.

The rest of the paper is organized as follows. Section 2 provides an overview of U.S.-China trade patterns and describes the "Anti-Comparative Advantage Puzzle". Section 3 constructs a theoretical model based on Eaton-Kortum (2002) for our estimation in later sections. Section 4 empirically tests the role of comparative advantage in explaining U.S.-China bilateral trade. Section 5 provides robustness checks. Section 6 concludes.

2.   Data

In this section, we describe the U.S.-China trade relationship focusing on structural changes in the past 15 years by reviewing their top 10 trading industries in 2011. We then test the correlation between the export structure of each and relative labor productivity, which reveals an anti-comparative advantage pattern regarding U.S. exports to China. We compare exports in high-tech sectors from the U.S. to China with those to India, to examine the possible effects from the demand side.

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[3]   Rodrik (2006) shows that China's export structure cannot be simply explained by its comparative advantage and free market; the variety of the exported goods from China is much more complicated than what is suggested by its income level, and moreover, this will be a key force for China's future economic growth. Rodrik's paper was followed up by further studies, such as Schott (2008), Wang and Wei (2010), Amiti and Freund (2010).

[4]   Autor et al. (2013) show that increasing exposure to Chinese imports can account for a substantial portion of unemployment in the US. It has also led to lower labor force participation and lower wages. Similarly effect on US job losses is also documented in Berger and Martin (2011) with evidence at the industry level.

2.1   Overview of U.S.-China Bilateral Trade Structures

Table 1 lists the top 10 industries measured by the value of the share of US exports to China in 2011, at the 6-digit HS code level. For comparison, the export shares in 1996 are also shown. We focus on manufacturing sectors. Here we define the export share of an industry in two ways: columns (1) and (2) use $Xshare^1$, defined as the industry's export value as a percentage of total US exports to China. Columns (3) and (4) use $Xshare^2$, defined as the industry's export value to China as a percentage of total US exports to the world in the same industry.[5] While $Xshare^1$ has been commonly used to measure trade structures, $Xshare^2$ standardizes the export value of each industry by the exporter's overall competitive advantage to the world, which makes comparisons across industries more sensible[6].

As Table 1 shows, according to Xshare[1], U.S. exports to China in 2011 were dominated by three categories: capital intensive products (integrated circuits, vehicles), primary goods (cotton, woods), and metal scraps (copper, aluminum and other ferrous wastes). The structure looked very different in 1996, when only cotton and air coolers were listed among the top exported products. The most significant change came from combined metal wastes, the share of which grew from 1% to 11% in 15 years. Furthermore, when using Xshare[2], it shows that in most of the top 10 industries, China has grown from a marginal buyer to a significant one, sometimes even the largest one. Again for listed metal wastes, more than half of the US's total exports are now sold to the Chinese market. This indicates that U.S. export patterns to China have changed significantly, vis-a-vis the rest of the world.

Following the same definition in Table 1, Table 2 presents the top 10 industries by export value of China's exports to the U.S. in 2011. The industries are mostly labor-intensive products, such as toys and footwear, and electronics products where China's role in the global supply chain has increased. As shown by $Xshare^2$, the U.S. is the main importer from China in these industries. Furthermore, comparisons between 1996 and 2011 indicate that the pattern of China's exports to the U.S. has changed, but similar to the way in which its export patterns to the rest of the world has changed.

2.2   The Anti-Comparative Advantage Pattern

According to Ricardian theory, a country should export more in sectors where it has a comparative advantage, and import more in sectors where it has comparative disadvantage. To test whether the U.S.-China trade structure fits the Ricardian prediction, we follow Golub and Hsieh (2000) and adopt

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[5]   Specifically, $XShare_{i,c}^1 = \dfrac{\text{Country c's export to its partner in sector i}}{\text{Country c's total exports to its partner}}$ (c=China, US), and

$$XShare_{i,c}^2 = \dfrac{\text{Country c's export to its partner in sector i}}{\text{Country c's total exports to the world in sector i}} \quad \text{(c=China, US)}$$

[6]   Otherwise if country *c* exports a low value of industry *i* to its partner, it may just reflect that country c is not a main exporter in this industry, and it exports little to the rest of the world as well.

relative labor productivity as a measure of comparative advantage. Labor productivity is defined as value-added per worker. Based on the extended Eaton-Kortum model that we derive in the next section, we expect a positive correlation between relative labor productivity and the export shares, calculated as a country's exports to its partner over the latter's expenditure on home-produced goods (output minus export) [7], labeled as *Xshare³*. As a robustness check, we calculate the correlation between relative labor productivity and *Xshare¹* and *Xshare²* as defined above. The above variables require data from the U.S. Census, UN COMTRADE, NBER-CES, and the Annual Industrial Enterprise Survey of China's National Bureau of Statistics. These databases have different industry classifications and different time spans, which we harmonize into 240 manufacturing industries from 1998 to 2008.[8] The time coverage allows us to utilize actual trade data and Chinese productivity data for the whole period, while US productivity after the year 2006 is inferred from that of 2005[9].

Table 3 summarizes the correlation coefficients between U.S.-China export shares and relative labor productivity in the respective industries, with the last two columns based on *Xshare³*, left and middle two on *Xshare¹* and *Xshare²* respectively. Since 2000, U.S. exports started to show an abnormal pattern: under all three definitions, export shares became negatively correlated with relative productivity, and the correlation coefficients have become increasingly negative in more recent years. That is, the U.S. appears to export relatively smaller volumes to China in industries in which it has a larger comparative advantage. The larger the comparative advantage is, the less the U.S. exports to China, relative to the rest of the world. On the other hand, China's exports to the U.S., as columns (2) (4) and (6) show, present a pattern which is more consistent with the theory. Overall China's export patterns to the U.S. are consistent with the theory of comparative advantage.

2.3   China-India Comparison

The U.S. is widely regarded as having a comparative advantage in high-tech products compared to developing countries. However, the anti-comparative advantage pattern in US exports to China could be driven by the demand side. We lack sufficient information to examine the demand side effect fully. A naïve and simple test is to compare the structure of US exports to China with its exports to a similar developing country, India.

Table 4 lists the 15 most skill-intensive industries in the US and their skill intensity (as in column (1) [10]). Columns (2) to (5) give the export shares to China and India respectively, where Xshare[1] follows the

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[7] $\frac{X_j^{ni}}{X_j^{nn}}$ defined in equation (5) on page 7.

[8]   The industry classification is harmonized between 4-digit Standard Industrial Classification (SIC, 1987 version) and the China's 4-digit Industrial Classification.

[9]   NBER-CES database only provide data till the year of 2005. Therefore, we assume U.S. labor productivity didn't change since 2005, and use the value of 2005 as proxies for 2006 to 2008.

[10]   Here we use U.S. skill intensity to measure the technology content of each industry. The definition of skill intensity is skilled labor income divided by total income. The data we use are also taken from the NBER-CES dataset. It adopts the 4-digit Standard Industry Classification (SIC), which provides more than 400 disaggregated industries.

same definition as before, and Xshare[2]$_{std}$ is the standardized Xshare[2], calculated as Xshare[2] divided by China's (or India's) share in U.S. total exports. Interestingly, export shares on both definitions are almost always larger for India than for China.

From the simple descriptive statistics above, it seems that 1) the US exported less to China in those products in which it had a comparative advantage, and 2) the US exported a greater share of those products to India, though the two importers are of similar size. What drives such an anti-comparative advantage pattern? In the following sections, we develop a theoretical model based on Eaton and Kortum (2002). It takes into consideration demand size, trade costs, and production costs etc. at the industry level. We then empirically test the importance of comparative advantage in determining U.S.-China bilateral trade.[11]

3.   The Model

This section extends the Eaton and Kortum (2002) model to multiple sectors. This setup leads to a gravity equation investigating how sectoral bilateral trade is determined. Consumers in the two countries have the same preference over the final goods, with utility given by:

$$U(Q_1, \dots, Q_N) = \prod_{j=1}^{N} Q_j^{a_j} \tag{1}$$

where Q_j is the quantity of the final good of sector j ($j = 1, \dots, N$) and a_j is the expenditure share of good j with $a_j \in (0,1)$, and $\sum_{j=1}^{N} a_j = 1$. Each sector j is composed of a continuum of varieties, indexed by $\omega_j \in [0,1]$ and represented by:

$$Q_j^n = \left(\int_0^1 q_j^n(\omega_j)^{(\sigma-1)/\sigma} d\omega \quad_j \right)^{\sigma/(\sigma-1)} \tag{2}$$

where $q_j^n(\omega_j)$ is the quantity of variety ω_j in sector j consumed in country n. $\sigma > 0$ is the elasticity of substitution.

Let c_j^i be the unit production cost for the prospective exporter of product j in country i. Country i's efficiency in producing variety ω_j of sector j is denoted as $z_j^i(\omega_j)$ and follows the Frechet distribution:

$$F_j^i(z) = e^{-T_j^i z^{-\theta}}$$

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[11]   Exploring all possible explanation of this pattern is beyond the scope of this paper. Intuitively it might be driven by the restricted supply from U.S., as well as sluggish demand from China in products that U.S. has comparative advantage. However, above comparison between China and India implies that it's more likely to be a supply side story. Most likely, U.S. performed special export control policy towards China. See Section 5 for more details.

where $T_j^i > 0$ and $\theta > 1$. The distribution is independent across sectors and countries. A larger T_j^i implies better technology and a bigger θ implies less heterogeneity across varieties within the sector. Let d_j^{ni} be the trade cost to deliver one unit of goods from country i to country n, $d_j^{ni} > 1$ for $n \neq i$ and $d_j^{nn} = 1$. We assume that triangular inequality holds.

For a competitive market, we have country *n*'s import price of variety ω from country *i*:

$$p_j^{ni}(\omega) = \frac{c_j^i d_j^{ni}}{z_j^i(\omega)}$$

where the unit production cost c_j^i is given by a Cobb-Douglas aggregate index across different factors *f*, namely, $c_j^i = \prod_{f=0}^{F}(w_f^i)^{s_{jf}}$.

Following the analysis by Eaton and Kortum (2002), exports from country *i* to country *n* in sector *j* are given by:

$$X_j^{ni} = \frac{T_j^i(c_j^i d_j^{ni})^{-\theta}}{\Phi_j^n}Q_j^n = \frac{T_j^i(c_j^i d_j^{ni})^{-\theta}}{\sum_{s=1}^{N} T_j^s(c_j^s d_j^{ns})^{-\theta}}Q_j^n \tag{3}$$

where Q_j^n is country *n*'s expenditure in sector *j*. Note that the sectoral output that country *n* produces for her own market, which is a proxy for home-market demand, is:

$$X_j^{nn} = \frac{T_j^n(c_j^n)^{-\theta}}{\sum_{s=1}^{N} T_j^s(c_j^s d_j^{ns})^{-\theta}}Q_j^n \tag{4}$$

Using equations (3) and (4), we have:

$$\frac{X_j^{ni}}{X_j^{nn}} = \frac{T_j^i(c_j^i d_j^{ni})^{-\theta}}{T_j^n(c_j^n)^{-\theta}} = \left(\frac{T_j^i}{T_j^n}\right) \cdot \left(\frac{c_j^i}{c_j^n}\right)^{-\theta} \cdot d_j^{ni-\theta} \tag{5}$$

Therefore, country *n*'s import value in sector *j* from country *i*, relative to its expenditure on home production of sector *j*, depends on country *i*'s sectoral productivity relative to country *n* (i.e., $\frac{T_j^i}{T_j^n}$), country *i*'s relative production costs in producing j (i.e., $\frac{c_j^i}{c_j^n}$), and trade costs between the two countries (d_j^{ni}). Taking logs, we obtain a gravity equation in equation (6), which we test empirically in the following section:

$$lnX_j^{ni} = lnX_j^{nn} + ln\frac{T_j^i}{T_j^n} - \theta ln\frac{c_j^i}{c_j^n} - \theta ln d_j^{ni} \qquad (6)$$

4.   Empirical Results in Bilateral Trade

Based on equation (6), we propose the following econometric models for empirical analysis:

$$\ln EX_j^{us} = \beta_0 + \beta_1 \ln HME_j^{cn} + \beta_2 \ln RTech_j^{us/cn} + \beta_3 \ln R(K/L)_j^{us/cn} + \beta_4 \ln Tariff_j^{cn} + \varepsilon_j \qquad (7)$$

$$\ln EX_j^{cn} = \beta_0 + \beta_1 \ln HME_j^{us} + \beta_2 \ln RTech_j^{cn/us} + \beta_3 \ln R(K/L)_j^{cn/us} + \beta_4 \ln Tariff_j^{us} + \varepsilon_j \qquad (8)$$

The dependent variable EX_j^{us} is U.S.'s export to China of industry j, and EX_j^{cn} indicates China's exports to the U.S. in the same industry. Both variables are obtained from the U.S. Census Merchandise of Export/Import data. HME_j^{cn} and HME_j^{us} is home market expenditure (output minus export) at the industry-level, representing the importer's demand for home produced products. $RTech_j^{us/cn}$ and $RTech_j^{cn/us}$ define industry-level relative technology, with the numerator in the superscript denoting the exporter and the denominator denoting the importer. In this and the following sections, technology is mainly measured by labor productivity and TFP. In the multilateral regressions, we use revealed comparative advantage to proxy for productivity. Similarly, $R(\frac{K}{L})_j^{us/cn}$ and $R(\frac{K}{L})_j^{cn/us}$ are relative capital-labor ratios at the industry level, which reflect the relative factor prices given a Cobb-Douglas production function and therefore relative production costs across industries. Data for productivity and the endowment variables are based on the U.S. NBER-CES dataset and China's Annual Survey of Industry Production. Finally, bilateral trade costs are measured by import tariff rates at the industry level, denoted as $Tariff_j^{cn}$ and $Tariff_j^{us}$ respectively. Tariff data are from the WITS database. Note that the distance between both countries doesn't change across industry so this is not included as a variable in the bilateral regressions.

4.1   Benchmark Results

Using U.S.-China panel trade data for around 240 industries from 1998 to 2008, we use the econometric specifications given by equations (7) and (8) to test for the "Anti-Comparative Advantage Puzzle". Regression outcomes are summarized in Table 5. The first three columns focus on the U.S.'s exports to China, and the other three columns examine China's export to the US. Columns (1) and (4) give the benchmark results, following our theoretical model. Columns (2) and (5) include the exporter's industry level GDP to control for its production capacity, and year fixed effects to control for aggregate shocks. Columns (3) and (6) add industry fixed effects to control for industry specific shocks; however, there is a possibility that the industry fixed effect is too strong to rule out cross-industry differences in comparative advantage determining trade structure. Therefore we mainly rely on results with only year fixed effects controls, namely columns (2) and (5). Across all specifications,

the relative productivity coefficients for the first three columns are negative while those for the last three columns are positive. This indicates that the more productive Chinese industries (relative to the U.S.) export more to the U.S., while more productive American industries (relative to China) export less to China. As expected, the effect of sectoral home-market expenditure and GDP are both positive (or not significant). The US exports more in more capital intensive sectors according to column (1) and (2). The negative sign of relative capital intensity in column (4) indicates that China exports more to the US in its more labor intensive sectors, but in columns (5) and (6) it becomes less significant. As expected, the sectoral exports become less if the tariff rate charged by the importing country is higher. With the notable exception of the anti-comparative advantage patterns in US's exports, the regression results are consistent with the theory.

4.2   Robustness Checks

We add three robustness tests to further examine the "anti-comparative advantage puzzle" found in the above.

4.2.1   Other Measurements of Technology

We first replace labor productivity with total factor productivity (TFP), measured via the Solow Residuals. The industry level TFP is based on a three-factor Cobb-Douglas production function which includes labor, capital and intermediary inputs. The labor and intermediary shares are estimated by expenditure on these inputs divided by total output, and the capital share is derived as the residual. Log TFP is therefore calculated as log real output minus the share of each input times their logged value in real terms. Deflators for Chinese input and output are obtained from Brandt, Van Biesebroeck and Zhang (2012), and US deflators come from the NBER-CES database.

Results are summarized in Table 6. The coefficients for relative TFP remain the same sign and are significant as those in Table 5, except for column (2). Thus, the anti-comparative advantage puzzle still holds.

4.2.2   Excluding Metal Products

As presented in Table 1, metal scraps accounted for 11% of U.S. exports to China in 2011. China is the most important buyer for U.S. waste metals. One possible explanation is that as a mature post-industrial country, the United States has an abundant endowment in scrap metal, while a developing country like China is relatively scarce in such resources. This is consistent with the Heckscher-Ohlin factor endowment theory of international trade. Therefore, we drop all metal and metallic products from U.S. exports to China, and redo the regressions with year fixed effects. Relative technology is measured by both labor productivity and TFP. Results are reported in Columns (1) and (2) of Table 7. It shows that almost all variables have the same sign and significance as in the benchmark results; in particular, the anti-comparative advantage puzzle remains.

4.2.3   Excluding Processing Trade

One prominent feature in U.S.-China bilateral trade is the prevalence of processing trade. It is therefore natural to ask whether the pattern of U.S. exports to China could be distorted by those products. So we further exclude processing exports in our regression. Due to data unavailability, we restrict the panel data time coverage to 2000 to 2006. Results are reported in columns (3) and (4) of Table 7. U.S./China relative technology, whether measured by labor productivity or TFP, has a negative effect on U.S. non-processing exports to China as before.

5.   Empirical Results in Multilateral Trade

Is the anti-comparative advantage pattern specific to US-China trade, or a common phenomenon affecting U.S. exports to other countries as well? To answer this question, we extend our empirical model to a multiple country framework. Equation (7) is applied to all countries that import from the U.S., with the importer's home-market expenditure replaced by the importer's sectoral GDP due to data limitations. Export and tariff data are from the WITS database. The U.S. and the importing countries' GDP and capital intensity[12] at the industry level are taken from the United Nations Industrial Development Organization (UNIDO) database. Chinese data are from the Annual Survey of Industrial Enterprises. Note that in multilateral regressions, after controlling for industry level tariffs, there are still other country-specific trade costs that affect U.S. exports to other countries (i.e., distance). We use country dummies to further control these factors.

In terms of technology, due to limitations in data quality and availability, we adopt Balassa's (1965) definition of Revealed Comparative Advantage (*RCA*).   The *RCA* of country *c* in industry *i* is calculated directly using international trade data according to Equation (9). RCA_i^c >1 indicates country *c*'s export share is larger than the world's average export share in industry *i*, hence country *c* is considered to have a comparative advantage in this industry relative to the rest of the world. The relative technology can therefore be represented as exporter-to-importer's relative RCA.

$$RCA_j^c = \frac{country\ c's\ export\ in\ industry\ i/country\ c's\ total\ export}{world\ export\ in\ industry\ i/world\ total\ export} \qquad (9)$$

To harmonize variables from different sources, we adopt the International Standard Industrial Classification (ISIC) rev.3 for our multilateral analysis, which yields over 100 manufacturing industries for each country. The UNIDO database has many missing values, and data quality varies widely by country. We therefore filter our country sample by setting a minimum requirement of 70 industries with all variables available, which leaves us with a sample of 37 importing partners for the U.S., including China. See Table A1 in the appendix for a detailed country list.

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[12]   Capital stock is not directly available in the UNIDO dataset. Instead, we use industry-year specific investment data which was available in UNIDO, and apply a 15-year double declining balance method (Leamer, 1984, pages 230-234). The initial year is 1970. Investment deflators are from the Penn World Table.

We first run a full sample regression with both country and year fixed effects, as column (1) in Table 8 shows. Here the coefficients should again be interpreted as cross-industry differences. It shows that the U.S./importer's relative RCA has a positive sign, indicating that the U.S. exports more in industries where it has a higher relative RCA, consistent with the theoretical model and standard trade theories. All other variables have their expected sign as well.

A China dummy, which equals 1 when the importing country is China and zero otherwise, is interacted with the U.S./importer's relative RCA. We report the result in column (2), which includes country and year fixed effects. Interestingly, the interaction term is negative and highly significant. This indicates that US exports to China are significantly different from US exports to other countries in our sample, which once again supports the anti-comparative advantage pattern that we documented earlier. The above tests are repeated for India and Indonesia, as columns (3) and (4) of Table 8 show, revealing that U.S.'s exports to India also show an abnormal pattern, but this is smaller in scale and less significant, while U.S.'s exports to Indonesia are consistent with the comparative advantage theory.

6.   Discussions

A full investigation of the causes of the "Anti-Comparative Advantage Puzzle" in U.S.'s exports to China is beyond the theme of this paper. Complaints have been made by China's senior trade officials on U.S. restrictions on high-tech exports. It has been reported that 2,400 categories of dual-use commodities are banned for export to China by the US government (Chen, 2012).[13] There is a growing body of evidence that U.S. restrictions on exports are outdated and may negatively affect US companies' export opportunities to China (AmCham China, 2009).[14] In Appendix B we provide a brief review of U.S. export restrictions vis a vis China.

The ideal way to test whether US export controls may explain the anti-comparative advantage puzzle that we have found in this paper is to construct an "US export control index", to add it into the regression for U.S. export to China as an additional control, and to see whether the coefficient on comparative advantage becomes significantly and positive with the control variable. Unfortunately, we lack sufficient information to build a continuous index consistent with our industry classifications[15]. As a compromise, we identify 34 control-related industries using a keyword match between the detailed list of banned goods at a product level and our industry classification (see Table B2 in the Appendix). This approach is limited by its inability to reflect the strength of US's controls over each industry.

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[13]   The claim was made by Mr. CHEN Deming, the former Minister of the Ministry of Commerce of China, in the 2012 China Development Forum. See http://english.cntv.cn/program/newshour/20120319/114831.shtml

[14]   The report was jointly conducted by AmCham China and the American Chamber of Commerce in Shanghai. An abstract of the research could be found online: http://www.amchamchina.org/article/5011

[15]   The most authorized information regarding US export control comes from The US Department of Commerce's Bureau of Industry and Security (http://www.bis.doc.gov/licensing/exportingbasics.htm). It lists 9 categories of dual-use products required to go through special procedure to be sold abroad (see Table B1 in the Appendix for details). These categories are too broad for our analysis, while the corresponding detailed product list follows unique classification method, which is very difficult to be harmonized with our industry classification.

However, comparing the US/China comparative advantage between control-related industries and the others might shed some light on the cause of the puzzle.

As Table 9 shows, US/China relative labor productivity and relative TFP are both significantly higher for control-related industries. This indicates that the intensity of U.S. export controls might be positively correlated with US/China comparative advantage, and the previous regression coefficient for US/China relative productivity may reveal a composite effect of both comparative advantage and U.S. export controls. Specifically, in equation (6), the trade costs term d_j^{ni} could be decomposed into the arithmetic product of two sub-terms, d_j^{ni*} traditional trade costs, and $control_j^{ni}$ as the US control intensity, which is a function of T_j^i/T_j^n. ubstituting the above into equation (6), we derive: S

$$lnX_j^{ni} = lnX_j^{nn} + ln\frac{T_j^i}{T_j^n} - \theta ln\frac{c_j^i}{c_j^n} - \theta\ln(d_j^{ni*} * control_j^{ni}(\frac{T_j^i}{T_j^n}))$$

which implies:

$$lnX_j^{ni} = lnX_j^{nn} + \left(ln\frac{T_j^i}{T_j^n} - \theta\ln control_j^{ni}\left(\frac{T_j^i}{T_j^n}\right)\right) - \theta ln\frac{c_j^i}{c_j^n} - \theta lnd_j^{ni*} \qquad (10)$$

The negative sign on the comparative advantage term (represented by the relative productivity) that we found in the regression may be the composite effect of comparative advantage and export controls. If we are able to properly take account of export controls, we should be able to see the "Anti-Comparative Advantage Puzzle" disappear or weakened.

7.   Conclusion

Since China's WTO accession in 2001, the U.S.-China trade imbalance has grown, and has become a major economic and political issue between the two countries. Instead of focusing on the exchange rate, which seems to be a major concern for the trade imbalance, this paper explores the trade structure between the two countries and provides a new insight to the trade imbalance between China and the U.S..

We show that this is a puzzle in U.S.-China bilateral trade patterns. The U.S. exports less to China in the sectors where it has greater comparative advantage; while China's export to the U.S. fit the theory of comparative advantage. Such a pattern is contrary to the prediction of standard comparative advantage theory, thus we label it as an "Anti-Comparative Advantage Puzzle". Intuitively, this puzzle could be driven by U.S. restrictions on exports to China, or other common factors that affect bilateral trade structures. However, comparing U.S. high-tech exports to China with India indicates China might be treated differently, and mildly point towards a supply side story.

On top of all these findings, we introduce a theoretical model which generates a bilateral trade determination function at an industry level. It takes into consideration the size of demand, trade costs, production costs, as well as comparative advantage. We use the model to empirically test the role of comparative advantage in U.S.-China bilateral trade. Results show that U.S. exports to China follow an Anti-Comparative Advantage pattern, a result that survives various robustness checks. Multilateral regressions further indicate China has a very special position in the U.S.'s world export market, which further rules out the possibility of a demand side story.

As pointed out in the AmCham China report, US companies have lost hundreds of millions in sales due to real and perceived restrictions arising from US export controls. In almost all cases where sales were lost, international non-US competitors provided equivalent products or services. Our findings suggest the following policy implications. To solve the U.S.-China trade imbalance, increasing U.S. exports to China could be mutually beneficial. In particular, increasing exports to China in sectors where the U.S. has greater comparative advantages should be a good starting point.

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Table 1. Top 10 Industries that U.S. Exported to China in 2011

Rank of 2011	Industry (HS6)	% of U.S. total export to China (Xshare[1])		% of U.S. total export in this industry (Xshare[2])	
		2011	1996	2011	1996
		(1)	(2)	(3)	(4)
1	**Copper waste and scrap**	**5%**	**0.5%**	**69%**	**8%**
2	Electronic integrated circuits, monolithic	4%	0.4%	13%	1%
3	Vehicles, Spark-ignition Engine 1500~ 3000cc	4%	0.0%	13%	0.1%
4	**Aluminum waste and scrap**	**4%**	**0.3%**	**72%**	**10%**
5	Cotton (Not Carded or Combed)	4%	7.2%	30%	27%
6	**Other Ferrous Waste and Scrap**	**2%**	**0.3%**	**17%**	**4%**
7	Vehicles, Spark-ignition Engine>3000 cc	2%	0.0%	10%	0.0%
8	Air-coolers, Air Purifiers	2%	1.3%	14%	3%
9	Unbleached Kraft paper or paperboard	2%	0.2%	68%	10%
10	Tropical woods	1%	0.1%	54%	0.5%

Table 2. Top 10 Industries China Exported to the U.S. in 2011

Rank of 2011	Industry (HS6)	% of Chinatotal export to U.S. (Xshare[1])		% of China total export in this industry (Xshare[2])	
		2011	1996	2011	1996
		(1)	(2)	(3)	(4)
1	Portable digital automatic data processing machines (ADP), weight<10 kg	11%	0.1%	33%	44%
2	Transmission Apparatus Incorporating Reception Apparatus	3%	0.1%	16%	7%
3	Reception Apparatus For Color Television	2%	0.1%	33%	4%
4	Parts and Accessories of the ADP Machines	2%	2.2%	18%	34%
5	Storage units	2%	1.3%	33%	30%
6	Other apparatus	2%	0.0%	19%	14%
7	Other printing machinery	2%	0.0%	28%	5%
8	Other Toys	1%	3.1%	36%	47%
9	Other Footwear With Uppers of Leather	1%	5.2%	50%	69%
10	Input or output units for ADP machines	1%	1.8%	28%	23%

Source: World bank WITS database (UN Comtrade)

Table 3. Correlation between Export Shares and Exporter-to-Importer's Relative Productivity, 1998-2008

year	Corr ($Xshare^1$, relative productivity)		Corr ($Xshare^2$, relative productivity)		Corr ($Xshare^3$, relative productivity)	
	(1) U.S. to CN	(2) CN to U.S.	(3) U.S. to CN	(4) CN to U.S.	(5) U.S. to CN	(6) CN to U.S.
1998	0.043	0.203	0.024	0.235	0.086	0.238
1999	0.025	0.139	0.000	0.116	0.062	0.188
2000	**-0.027**	0.074	**-0.060**	0.101	**-0.014**	0.135
2001	**-0.060**	0.191	**-0.076**	0.135	**-0.055**	0.231
2002	**-0.026**	0.075	**-0.025**	0.127	**-0.006**	0.172
2003	**-0.117**	0.038	**-0.148**	0.091	**-0.112**	0.160
2004	**-0.129**	0.101	**-0.136**	0.162	**-0.083**	0.188
2005	**-0.123**	0.054	**-0.115**	0.115	**-0.066**	0.122
2006	**-0.107**	-0.037	**-0.135**	-0.044	**-0.064**	0.034
2007	**-0.081**	-0.035	**-0.150**	0.078	**-0.072**	0.084
2008	**-0.106**	-0.087	**-0.175**	-0.032	**-0.046**	0.002

Source: Author's calculation.

Table 4. U.S. High-Tech Exports to China and India, SIC4, 2005

SIC code	Products	Skill-intensity of U.S.	$XShare^1$		$Xshare^2_{std}$	
			China	India	China	India
3769	Space vehicle equipment	0.808	0.0%	0.0%	0.01	0.13
3826	Analytical instruments	0.801	1.3%	1.6%	1.62	2.03
3825	Instruments to measure electricity	0.794	1.4%	1.7%	1.52	1.79
3577	Computer peripheral equipment	0.787	0.9%	1.8%	0.80	1.68
3578	Calculating, accounting equipment	0.783	0.1%	0.1%	1.30	1.27
3812	Search and navigation equipment	0.772	0.4%	1.0%	0.66	1.74
3661	Telephone and telegraph apparatus	0.756	1.7%	3.1%	1.41	2.50
3844	X-ray apparatus and tubes	0.754	0.6%	1.0%	1.46	2.53
3663	Radio, communications equipment	0.748	0.4%	2.4%	0.47	2.82
3571	Electronic computers	0.741	3.2%	3.7%	1.13	1.30
2835	Diagnostic substances	0.731	0.2%	0.6%	0.38	1.02
3579	Office machines	0.726	0.1%	0.1%	1.00	0.84
3572	Computer storage devices	0.707	0.2%	0.8%	0.49	2.49
3669	Communications equipment	0.705	0.1%	0.2%	1.01	1.96
3489	Ordnance and accessories	0.704	0.0%	0.0%	0.01	0.05

Table 5. Benchmark Regressions for U.S.-China Bilateral Trade, 1998 to 2008

Dependent variables: Log U.S. export to China in column (1) to (3), and Log China export to the U.S. in column (4) to (6)

VARIABLES (in log terms)	U.S. export to China			China export to the U.S.		
	(1)	(2)	(3)	(4)	(5)	(6)
Importer's consumption of its own production by industry	0.480***	0.138***	0.159***	0.460***	0.174***	0.149**
	(0.0302)	(0.037)	(0.040)	(0.057)	(0.053)	(0.060)
Exporter's GDP by industry		0.607***	0.375***		0.072*	0.064
		(0.067)	(0.101)		(0.040)	(0.042)
Relative labor productivity, Exporter/Importer	**-0.428***	**-0.255***	**-0.130***	**1.569***	**0.182**	**0.139***
	(0.0545)	(0.070)	(0.075)	(0.037)	(0.071)	(0.072)
Relative K-intensity, Exporter/Importer	0.293***	0.208***	0.043	-1.050***	0.096	0.141*
	(0.0654)	(0.079)	(0.088)	(0.068)	(0.079)	(0.082)
Tariff charged by importer	-0.158***	-0.090**	-0.042	-0.097***	-0.057***	-0.058***
	(0.0347)	(0.035)	(0.036)	(0.021)	(0.019)	(0.019)
Constant	9.533***	9.405***	10.431***	14.067***	13.308***	13.788***
	(0.618)	(0.728)	(0.922)	(0.857)	(0.950)	(1.067)
Observations	2,433	2,433	2,433	2,370	2,370	2,370
Industry FE	NO	NO	YES	NO	NO	YES
Year FE	NO	YES	YES	NO	YES	YES

Table 6. Robustness Check: Technology Measured by Relative TFP, 240 Industries, 1998 to 2008

Dependent variables: Log U.S. export to China in column (1) and (2), and Log China export to the U.S. in column (3) and (4)

VARIABLES (all in log terms)	U.S. export to China		China export to the U.S.	
	(1)	(2)	(3)	(4)
Importer's consumption of its own production by industry	0.520***	0.177***	0.146***	0.147***
	(0.027)	(0.036)	(0.055)	(0.051)
Exporter's GDP by industry	0.494***	0.479***	0.674***	0.089**
	(0.066)	(0.064)	(0.026)	(0.038)
Relative TFP, Exporter/Importer	**-0.625***	**0.074**	**1.079***	**0.451***
	(0.097)	(0.119)	(0.100)	(0.120)
Relative K-intensity, Exporter/Importer	0.086	0.043	0.092	0.294***
	(0.067)	(0.067)	(0.071)	(0.069)
Tariff charged by importer	-0.197***	-0.092**	-0.073***	-0.055***
	(0.035)	(0.036)	(0.021)	(0.019)
Constant	4.242***	9.141***	5.066***	12.983***
	(0.642)	(0.727)	(0.922)	(0.946)
Observations	2,422	2,422	2,347	2,347
Industry FE	NO	NO	NO	NO
Year FE	NO	YES	NO	YES

Table 7. Robustness Check: Excluding Metal Products and Processing Trade, 240 Industries, 1998 to 2008

Dependent variable: Log U.S. export to China at industry level

VARIABLES (all in log terms)	No metal products: 1998-2008		No processing trade: 2000-2006	
	(1)	(2)	(3)	(4)
China's consumption of its own production by industry	0.143***	0.179***	0.0979**	0.150***
	(0.0370)	(0.0356)	(0.0460)	(0.0436)
U.S. GDP by industry	0.596***	0.504***	0.620***	0.528***
	(0.0682)	(0.0640)	(0.0807)	(0.0782)
Relative labor productivity, U.S./China	**-0.254***		**-0.303***	
	(0.0693)		(0.0875)	
Relative TFP, U.S./China		**-0.117**		**-0.160**
		(0.0982)		(0.173)
Relative K-intensity, U.S./China	0.204***	0.0242	0.365***	0.169*
	(0.0785)	(0.0648)	(0.103)	(0.0905)
Tariff charged by China	-0.0957***	-0.0955***	-0.0635	-0.0589
	(0.0350)	(0.0350)	(0.0615)	(0.0618)
Constant	9.433***	8.961***	10.69***	10.06***
	(0.733)	(0.729)	(0.930)	(0.947)
Observations	2,360	2,360	1,556	1,556
Number of industry	218	218	225	225
Year Fixed effect	YES	YES	YES	YES

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Table 8. Robustness Check: Multi-Lateral Regressions, 4-Digit ISIC, 1998 to 2008

Dependent variable: Log U.S. export to 37 countries at industry level

VARIABLES (all in log terms)	(1)	(2)	(3)	(4)
Importer's GDP by industry	0.099***	0.093***	0.099***	0.101***
	(0.016)	(0.016)	(0.016)	(0.016)
U.S. GDP by industry	0.672***	0.680***	0.673***	0.669***
	(0.028)	(0.028)	(0.028)	(0.028)
Relative RCA, U.S./importer	**0.087***	**0.103***	**0.091***	**0.080***
	(0.011)	(0.012)	(0.012)	(0.012)
China*Relative RCA		**-0.212***		
		(0.040)		
India*Relative RCA			-0.112*	
			(0.060)	
Indonesia*Relative RCA				0.220***
				(0.060)
Relative k-intensity, U.S./Importer	0.047**	0.042**	0.046**	0.044**
	(0.020)	(0.020)	(0.020)	(0.020)
Tariff charged by importer	-0.181***	-0.175***	-0.182***	-0.181***
	(0.014)	(0.014)	(0.014)	(0.014)
Constant	-6.881***	-6.951***	-6.908***	-6.866***
	(0.649)	(0.649)	(0.649)	(0.650)
Observations	9,539	9,539	9,539	9,539
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Table 9. US-to-China Comparative Advantage Comparison and T-test Results

Productivity measurement	Control-related industries Mean (std dev)	Control-irrelevant industries Mean (std dev)	T-test (H0: US/China comparative advantage is higher for control-related industries)
Labor productivity	0.94 (0.04)	0.79 (0.01)	Not reject at 1%
TFP	0.20 (0.03)	0.12 (0.01)	Not reject at 1%

Figure 1. Major U.S. Exports to China, 2000-2008 (in millions of U.S. $)

	2000	2004	2008	2000–2008 % Change
Waste & Scrap	$744	$2,508	$7,562	916%
Semiconductors & Other Electronic Components	$1,317	$3,565	$7,475	467%
Oilseeds & Grains	$1,048	$2,829	$7,316	598%
Aerospace Products & Parts	$1,770	$2,111	$5,470	209%
Resin, Synthetic Rubber, & Artificial & Synthetic Fibers & Filament	$660	$1,630	$3,523	433%
Total U.S. Exports	**$16,253**	**$34,721**	**$71,457**	**339%**

Source: U.S. International Trade Commission, *Interactive Tariff and Trade DataWeb* (Washington, DC).

Appendix A. Additional Tables and Figures

Table A1. List of Countries Used in the Multilateral Regression

No.	ISO3	Country	No.	ISO3	Country
1	AU.S.	Australia	20	LKA	Sri Lanka
2	AZE	Azerbaijan	21	LTU	Lithuania
3	BGR	Bulgaria	22	LVA	Latvia
4	BOL	Bolivia	23	MAR	Morocco
5	CHL	Chile	24	MEX	Mexico
6	CHN	China	25	MLT	Malta
7	COL	Colombia	26	MWI	Malawi
8	CYP	Cyprus	27	MYS	Malaysia
9	CZE	Czech Republic	28	NOR	Norway
10	ECU	Ecuador	29	NPL	Nepal
11	ETH	Ethiopia(excludes Eritrea)	30	OMN	Oman
12	GEO	Georgia	31	POL	Poland
13	HUN	Hungary	32	SGP	Singapore
14	IDN	Indonesia	33	SVK	Slovak Republic
15	IND	India	34	SVN	Slovenia
16	IRN	Iran, Islamic Rep.	35	SWE	Sweden
17	JOR	Jordan	36	TUR	Turkey
18	JPN	Japan	37	URY	Uruguay
19	KOR	Korea, Rep.			

Appendix B. The History of U.S. Export Control

The U.S. has a long history of export restrictions towards China, which can be dated back to the Cold War. In 1948, the U.S. proposed to establish Committee Controlling East-West Trade (COCOM) in order to implement military embargo against the socialist countries. Then in 1952, by the impact of the Korean War, COCOM set up the "China Commission", implementing stricter embargo policies on China than the Soviet Union and Eastern European; the ban list for China included 500 more items than the international ban list. Eventually, with China's economic development and the progress of U.S.-China diplomatic relation, the strength of U.S. export control towards China had been weakened gradually. However in 1989 the United States again suspended its cooperation with China on military-technical projects, and all other COCOM members announced the termination of their previous relax on high-tech exports to China. In 1995, the U.S. developed an export priority system based on the exporting products and their technology content, dividing countries in the world into 8 categories. China was drawn in the sixth category "Outsiders" together with India and Singapore, which is below the category of "Comrades" where Russia, Ukraine, Bulgaria and Romania belonged to, and over "The States of Concern" with members like Iraq, Iran, North Korea and Libya etc.

In 1996, the United States and other 32 western countries signed the "Wassenaar Agreement" (WA), deciding to implement the new control list and information exchange rules since November 1, 1996; China was still one of the banned countries. WA included two control lists: one is a list of dual-use goods and technologies; the other is the military list.

The most recent adjustment of U.S. export control policy occurred on June 19, 2007, when the Bureau of Industry Security in the U.S. Department of Commerce officially announced the "Revisions and Clarification of Export and Re-export Controls for the People's Republic of China (PRC); New Authorization Validated End-User; Revision of Import Certificate and PRC End-User Statement Requirements"[16]. This policy prohibited the exporting of 9 categories of products (See Table B1 below) to China, all of which are classified as with technologies likely to "enhance China's military strength". Besides, the U.S. "Validated End-User" plan regulates that only "Trusted clients" can import restricted goods without special authorization. By the end of 2009, only five companies in China had received such VEU status, but none of which is local owned enterprise.

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[16] "Revisions and Clarification of Export and Re-export Controls for the People's Republic of China (PRC); New Authorization Validated End-User; Revision of Import Certificate and PRC End-User Statement Requirements", Federal Register, 72(117), Tuesday, June19, 2007, Rules and Regulations, Department Of Commerce Bureau of Industry and Security.

Table B1. Product Categories of U.S. Export Control

Category	Description
0	Nuclear Materials, Facilities & Equipment (and Miscellaneous Items)
1	Materials, Chemicals, Microorganisms, and Toxins
2	Electronics
3	Computers
4	Telecommunications
5	Information Security
6	Sensors and Lasers
7	Navigation and Avionics
8	Marine
9	Propulsion Systems, Space Vehicles and Related Equipment

Table B2. U.S. Export Control Related Industries

Product Category	SIC and CIC harmonized Industry
0	Nuclear fuel
0, 2	Arms and Ammunition
0, 1, 2, 9	Pumping equipment
0, 8	Air compressors
1	Alkalies and chlorine gases
1	Nitrogenous fertilizers
1	Explosives
1	Carbon and graphite
1	Refractory ceramics
1	Smelting and refining of nonferrous metals
1	Medicinal chemicals and botanical products
1	Flat glass
1	Biological products
1, 2	Steel rolling process
1, 3	X-ray apparatus etc.
2	Carburetors and valves
2	Machine tools, metal cutting types
2	Machine tools, metal forming types
2	Welding and soldering equipment
2	Ball and roller bearings
3	Switchgear and switchboard apparatus
3	Electronic capacitors
3	Semiconductors
3	Electron tubes
4	Electronic components
4	Electronic computers
6	Optical instruments and lenses
6, 7	Search, detection, navigation etc.
8	Boiler
8	Photographic equipment and supplies
9	Internal combustion engines
9	Aircraft and parts
9	Guided missiles and space vehicles
9	Motors and generators