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Product Complexity, Exports, and Exchange Rates: Evidence from the Japanese Chemical Industry*

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Abstract

We investigate how exchange rates affect the Japanese chemical industry. Focusing on exports in a single industry from a single country reduces the influence of other factors that could cloud inference. We find that stock returns of firms linked to commoditized industries decrease when the yen appreciates. Also, since more complex products are less substitutable in international trade, we investigate whether they have lower price elasticities. We measure complexity using Hausmann and Hidalgo's (2009) product complexity index. We find that price elasticities are lower for more complex goods. These results suggest that exporting sophisticated products could reduce export and profit volatility arising from exchange rate swings.

JEL classification numbers: F14, F10
Keywords: Exchange rate elasticities; Product complexity index, Japan

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1. Introduction

Exchange rates impact trade prices, firm profitability, and trade flows. Export and import volatility in turn amplifies business cycle fluctuations. This paper uses the Japanese chemical industry to investigate whether certain types of goods are less exposed to exchange rate changes. The Japanese chemical industry is the country's second largest manufacturing industry, with annual shipments exceeding USD 400 billion.[**] Chemical firms provide super engineering plastics and elastomers for automobiles, fluorinated polyimide, photoresists, and etching gas for electronic parts and components, soda ash for glass, and other vital inputs to downstream industries.

Ito, Koibuchi, Sato, and Shimizu (2016) noted that an appreciating yen squeezes exporters' profitability by decreasing profit margins (if the appreciation is not passed through to higher prices abroad) or by lowering sales (if the appreciation is passed through to higher retail prices abroad). They investigated the exchange rate exposure of Japanese firms and industries using monthly stock returns for 227 companies over the January 2005 to December 2009 period. They regressed returns on the percentage change in the exchange rate and also in one specification on the return on the overall Japanese stock market. For the chemical industry, they reported that when the return on the Japanese market is included in the regression, a 10 percent depreciation of the nominal yen/dollar exchange rate is associated with a 5 percent increase in returns on the overall chemical industry and slightly more than a 1 percent increase in returns on the medicinal chemical sector.

[**] These data come from the Japanese Chemical Industry Association website. The URL is www.nikkakyo.org.

We disaggregate the chemical industry further to investigate whether exchange rates affect different parts of the industry differently. Ito, Koibuchi, Sato, and Shimizu (2018) observed that firms exporting differentiated products are better able to keep their yen exporting prices and thus their profit margins fixed, at least in the short run. Researchers at the International Monetary Fund, the Asian Development Bank, and other institutions have highlighted product complexity as a key factor influencing trade elasticities (see, e.g., Arbatli and Hong, 2016, Abiad et al., 2018, and Asian Development Bank, 2018). They noted that complex products are less substitutable in international trade and should therefore have lower price elasticities.

The advantage of focusing on products within the chemical industry is that we minimize differences in other factors that could affect our estimates. For instance, producing different chemical products requires similar skills and knowhow whereas producing textiles and automobiles require different capabilities. The advantage of employing exports from a single country is that we minimize differences in other factors such as regulatory and macroeconomic environments that can confound inference. The advantage of focusing on exports from an advanced country is that developed countries often produce high quality goods domestically and outsource low-quality varieties of the same good to lower wage countries (Bernard, Fort, Smeets, and Warzynski, 2020). Thus including exports from several countries in a single regression to estimate elasticities can conflate similar products of different qualities. The advantages of using Japanese export data are that they are measured carefully and that Japan has exported many types of chemicals over a long period of time. The accurate and abundant cross sectional and time series data can help to uncover how different types of chemical exports respond to exchange rate changes.

We first estimate exchange rate exposures for 51 Japanese chemical firms. We find that Japanese chemical firms linked to industries such as automobiles and electronic parts and components (ep&c) are harmed the most when the yen appreciates. Ito, Koibuchi, Sato, and Shimizu (2018) reported that the automobile market in places like the U.S. is so competitive that Japanese automakers must invoice in the importing country's currency. Katz (2012) noted that integrated circuits and similar products have become commoditized and that Japanese producers must compete in this sector based on price. The automobile and ep&c sectors are thus exposed to yen appreciations. On the other hand, Japanese chemical firms linked with the pharmaceutical and biotechnology sectors are not harmed by appreciations. Sauré (2015) observed that prescription drugs often have low price elasticities because they are essential and covered by health insurance plans. The pharmaceutical and biotechnology sectors should thus be less exposed to appreciations.

We then investigate the relationship between product sophistication and trade elasticities for the Japanese chemical industry. We employ data on 93 different categories of chemical exports from Japan. We follow Arbatli and Hong (2016) in employing Hidalgo and Hausmann's (2009) product complexity index (PCI) to measure sophistication. We find a strong relationship between more complex products and lower price elasticities.

Several researchers have examined the relationship between technological sophistication and exchange rate elasticities for Switzerland. Like Japan, Switzerland has an advanced industrial structure and exports sophisticated products. The International Monetary Fund (2013) observed that Swiss exports may face limited price competition because they are advanced and valued for their brands.

Auer and Sauré (2011) estimated exchange rate elasticities employing annual bilateral trade data between 24 OECD countries over the 1972-2000 period. They reported smaller responses to exchange rates for Swiss exports than for exports from other OECD countries. They explained this by noting that Swiss exports are concentrated in high quality goods such as pharmaceuticals that have low price elasticities. They also found smaller exchange rate elasticities for Swiss exports of advanced products such as centrifuges and milling machines than for Swiss exports of ubiquitous products such as clothing and fish fillets.

Thorbecke and Kato (2018) estimated exchange rate elasticities using annual data on Swiss exports in several categories to major importers over the 1989-2014 period. Employing panel dynamic ordinary least squares (DOLS) methods, they reported that exchange rates do not affect exports for sophisticated sectors such as pharmaceuticals and watches. On the other hand, they found that appreciations reduce exports of medium-high-technology products such as capital goods and machinery.

Grossmann, Lein, and Schmidt (2016) estimated exchange rate elasticities for Swiss exports using sector-specific trade data from 1989Q1 to 2014Q4. They examined exports of 12 sectors from Switzerland to 24 destinations that receive 83% of Switzerland's exports. Employing an error correction model, they found that elasticities differ by sector. Agriculture, paper products, textiles and clothing, leather, and similar products have higher elasticities. Machinery and precision instruments have lower elasticities. Pharmaceuticals and chemicals have low elasticities.

In previous work on Singapore Arbatli and Hong (2016) investigated whether more complex exports as measured by the PCI have lower exchange rate elasticities. Employing a Mean Group estimator and annual data at the Harmonized System (HS) 4-digit level from 1989 to 2013, they reported that products with higher PCIs have lower elasticities.

In previous work on Japan, Baek (2013) used an autoregressive distributed lag (ARDL) model over the 1991Q1-2010Q4 period and CPI-deflated real exchange rates to investigate

Japan's exports to South Korea at the Standard Industrial Trade Classification (SITC) 1-digit level. He found that SITC 6 exports (e.g. leather, iron & steel, non-ferrous metals) have a long run elasticity of 1.64; SITC 2 exports (crude materials other than fuels) an elasticity of 1.37; SITC 3 exports (fuels) an elasticity of -1.02; SITC 5 exports (chemicals) an elasticity of 0.94; and that SITC 7 (machinery and transportation equipment) and SITC 8 (e.g., furniture, luggage, footwear) exports are not affected by exchange rates. Baek posited that the zero exchange rate elasticity for machinery and transportation equipment occurred because these goods are essential for Korean firms to produce goods for re-export.

Sato, Shimizu, Shrestha and Zhang (2013) examined how Japanese exports in several International Standard Industrial Classification (ISIC) categories responded to rest of the world output and to industry-specific real effective exchange rates. They measured rest of the world output as a weighted average of 26 trading partners' industrial production indices. They employed a monthly VAR over the January 2001 to February 2013 period and assumed that rest of the world output is strictly exogenous and that the exchange rate is not affected in the same month by shocks to exports. They reported that a positive exchange rate shock (yen appreciation) will decrease Japanese exports in the transportation equipment (ISIC 34-35), office machinery (ISIC 30), electrical apparatuses (ISIC 31), and communications (ISIC 30) sectors. The effect is largest for transportation equipment exports, followed by office machinery and then electrical machinery and is smallest for communications exports.

Kato (2015) used panel DOLS and annual data on Japanese exports to 26 countries over the 1995-2011 period to estimate elasticities. He examined Japanese exports of high skill & technology intensive manufacturing and medium skill & technology intensive manufacturing. He obtained data on exports by skill level from the United Nations Conference on Trade and Development. For high skill & technology intensive exports, DOLS estimates with heterogeneous time trends indicate that a 10 percent yen appreciation would reduce exports by 13.6 percent. For medium skill & technology intensive exports, DOLS estimates with heterogeneous trends indicate that an appreciation would not affect exports. Kato suggested that medium technology goods may not be sensitive to exchange rates because of their role in regional supply networks.

Thorbecke and Salike (2020) used panel DOLS and annual data on exports from Japan and other major producers of 18 goods over the 1992-2016 period to estimate elasticities. They classified goods into four technology levels based on OECD classifications. They found that higher technology goods had lower elasticities. For aggregate chemical exports from France, Germany, Japan, and the US, they reported that a 10 percent appreciation would reduce exports by 1.1 percent.

Using disaggregated data can reduce the downward bias that is inherent in aggregate estimates (Orcutt, 1950). We estimate elasticities for 93 individual chemical exports from Japan to 188 countries over the 1995-2017 period. We find a wide range of elasticities for different chemical products.

The next section investigates the exchange rate exposure of Japanese chemical companies. Section 3 presents exchange rate elasticities for Japanese chemical exports. Section 4 concludes.

2. Investigating the Exposure of the Chemical Industry to Macroeconomic Variables

Our goal is to investigate how exchange rates affect the Japanese chemical industry. To do this, we first investigate how exchange rates affect stock prices. Finance theory holds that stock prices equal the expected present value of future cash flow. The response of chemical firms' stock prices to exchange rates should thus shed light on how exchange rates affect their future payout.

Many have investigated the exposure of stock returns to exchange rates (see, e.g., Dominguez and Tesar, 2006 and Jayasinghe and Tsui, 2008). To do this they regress company stock returns ($R_{i,t}$) on changes in the log of the exchange rate (Δe_t) and on the return on the country's aggregate stock market ($R_{M,t}$). According to the market model, the return on the aggregate stock market captures the impact of economy-wide factors on company returns. We also include the return on the world stock market ($R_{W,t}$) to capture the impact of factors in the rest of the world on returns. Finally, we include the percentage change in crude oil prices to reflect the research indicating that oil prices impact Asian economies (see, e.g., Thorbecke, 2019). We thus estimate the regression:

$$R_{i,t} = \alpha_i + \beta_{i,yen}\Delta Yen_t + \beta_{i,M} R_{M,t} + \beta_{i,W}R_{W,t} + \beta_{i,crude}\Delta P_{crude,t} + \varepsilon_{i,t} \ , \qquad (1)$$

where $R_{i,t}$ is the return on chemical firm *i*, ΔYen_t is the change in the log of the yen/dollar exchange rate, $R_{M,t}$ is the return on the aggregate Japanese stock market, $R_{W,t}$ is the return on the world stock market index, and $\Delta P_{crude,t}$ is the change in the log of the spot price for Dubai crude oil.

The data are daily and come from the Datastream database. The sample period extends from 4 September 2000 to 2 September 2020.[††] Augmented Dickey-Fuller tests allow rejection of the null hypothesis that the series have unit roots. Ordinary least squares (OLS) is thus used to estimate equation (1).

Before estimating equation (1) with returns on individual firms as the left hand side (lhs) variable we use returns on the overall Japanese chemistry industry ($R_{chem,t}$) as the lhs variable:

[††] For some companies, stock return data are not available starting 4 September 2000. In those cases the regressions start on the first date that the data are available.

$$R_{chem,t} = \underset{(0.023)}{0.046^{**}}\Delta Yen_t + \underset{(0.014)}{1.062^{***}}R_{M,t} + \underset{(0.015)}{0.060^{***}}R_{W,t} + \underset{(0.004)}{-0.001}\Delta P_{crude,t} + \cdots \quad (2)$$

Adjusted R-squared = 0.840, Standard error of regression = 0.00617, Heteroscedasticity and autocorrelation consistent standard errors in parentheses. Sample period = 4 September 2000 – 29 May 2020. ***[**] denotes significance at the 1% [5%] level.

The results indicate that returns on a portfolio of chemical company stocks increase when the yen depreciates, when the Japanese stock market increases, and when the world stock market increases. These findings imply that the chemical industry is thus exposed to a stronger yen and a slowdown in the Japanese and world economies.

To understand why, we estimate equation (1) for individual chemical companies. The results are presented in Table 1. For nine companies there is a statistically significant relationship between increases in the yen/dollar exchange rate (depreciations of the yen) and increases in returns. There are no companies with a statistically significant relationship between decreases in the yen/dollar rate (appreciations of the yen) and increases in returns.

Japanese chemical firms provide inputs to industries including automobiles, biotechnology, cement, construction, cosmetics, electronic parts and components, fertilizer, food, glass, healthcare, pharmaceuticals, plastics, and semiconductors. To investigate how the individual firms listed in Table 1 are related to these industries, we run the following regression of daily stock returns for each chemical firm on daily stock returns for these industries and for the overall Japanese stock market:

$$R_{i,t} = \alpha_{i,0} + \alpha_{i,1}R_{M,t} + \alpha_{i,2}R_{auto,t} + \alpha_{i,3}R_{biotech,t} + \alpha_{i,4}R_{cement,t} + \alpha_{i,5}R_{construc,t} + \alpha_{i,6}R_{cosmet,t} + \alpha_{i,7}R_{ep\&c,t} + \alpha_{i,8}R_{fertilizer,t} + \alpha_{i,9}R_{food,t} + \alpha_{i,10}R_{glass,t} + \alpha_{i,11}R_{healthcare,t} + \alpha_{i,12}R_{pharma,t} + \alpha_{i,13}R_{plastics,t} + \alpha_{i,14}R_{semico,t} + \varepsilon_{i,t}, \quad (3)$$

where $R_{i,t}$ is the return on chemical firm *i*, $R_{M,t}$ is the return on the aggregate Japanese stock market, and the other R's are the returns on the 13 industries listed above.

Table 2 reports the α_i coefficients for all of the industries in equation (3) that are statistically significant. The results are plausible. For instance, Kaneka which does research on anti-inflammatory drugs is exposed to the pharmaceutical sector. Denka, which works on cement, is exposed to the cement industry. Inabata which provides inputs for electronic components is exposed to the electronic parts and components sector.

Are industries with high exposures to exchange rates linked with certain downstream industries? To investigate this we regress the exchange rate betas ($\beta_{i,yen}$) for each chemical firm *i* from equation (1) on the corresponding α_i coefficients relating returns on firm *i* with returns on each industry from equation (3).

The results are presented in Table 3. There is a statistically significant relationship between the $\beta_{i,yen}$ coefficients and the α_i coefficients for the automobile, electronic parts and components, fertilizer, food, and plastics sectors. Thus chemical firms that benefit more from yen depreciations are those linked to these industries. The largest coefficients in Table 3 are associated with the automobile and electronic parts and components sectors. Nguyen and Sato (2019) found that a yen appreciation leads to large decreases in yen export prices for passenger cars. Thorbecke (2019) reported that a yen appreciation leads to large decreases in yen export prices for electronic parts and components. The profitability of these industries thus increases as the yen becomes weaker. It therefore makes sense that the profitability of upstream chemical firms that are related to these industries is also harmed by yen appreciations. In contrast, there is no relationship between firms linked to sophisticated sectors such as biotechnology and pharmaceuticals and their exchange rate elasticities.

3. Investigating the Relationship Between Product Sophistication and Exchange Rate Elasticities

In this section we investigate whether there is a relationship between product sophistication and exchange rate elasticities for the Japanese chemical industry. We measure sophistication using Hidalgo and Hausmann's (2009) PCI. Hidalgo and Hausmann posited that a product is sophisticated if only a few countries can make it and simple if it can be made ubiquitously. They employed the method of reflections to calculate PCIs for 1242 products at the Harmonized System (HS) 4-digit level.

For the chemical industry, many countries produce goods such as ammonia. This product is thus classified as ubiquitous. On the other hand, Japan produces 90% of the world's fluorinated polyimide and 70% of its etching gas (Obayashi, 2019). Since Japan is one of only a few countries that produce these goods, they are classified as complex.

We can obtain data on 93 categories of chemical exports (HS 28 and 29) at the 4-digit level and corresponding PCI values from the Atlas of Economic Complexity.[‡‡] Since PCI values flucuate from year to year, we use average PCI rankings among 1242 manufacturing exports over the 1995-2017 sample period to measure product complexity. The mean ranking among the 93 chemical categories is 437, the standard deviation is 255, and the values range from 33 to 1020. This wide cross-sectional variation in PCI rankings should help to identify in an econometric sense whether there is a relationship between elasticities and product complexity.

To calculate elasticities for Japan's chemical exports, we follow Bénassy-Quéré et al. (2019). They modeled exports from country i to country j of product p in year t, X_{ijpt}, using a series of fixed effects:

$$lnX_{ijpt} = \lambda_{ipt} + \mu_{jpt} + \nu_{ij} + \epsilon_{ijpt} \qquad (4),$$

where λ_{ipt}, μ_{jpt} and ν_{ij} represent fixed effects for exporter, product,time; importer,product,time; and importer,exporter respectively. The last term ϵ_{ijpt} is a random error term. Benassy-Queré et

[‡‡] The website for the Atlas is https://atlas.cid.harvard.edu.

al. (2019) included the natural log of the bilateral real exchange rate between country i and country j, $lnBRER_{ijt}$, yielding the equation:

$$lnX_{ijpt} = \beta lnBRER_{ijt} + \lambda_{ipt} + \mu_{jpt} + \nu_{ij} + \epsilon_{ijpt} \quad (5).$$

We estimate equation (5) with fixed effects along three dimensions (*j, p, t*) instead of four dimensions(*i, j, p, t*) because there is only one exporting country. Following Benassy-Queré et al. we also include real GDP (Y_{jt}) in the importing country as an additional control variable. We cannot include real GDP in Japan since it is collinear with the time fixed effect (μ_t). Our estimated equation is:

$$lnX_{jpt} = \beta_0 + \beta_1 lnBRER_{jt} + \beta_2 lnY_{jt} + \lambda_{jp} + \mu_t + \epsilon_{jpt} \quad (6).$$

We follow Benassy-Queré et al. (2019) in measuring (X_{jpt}) as the value of exports. Bilateral FOB export data from Japan to 188 countries at the HS 4-digit level for 93 chemical goods between 1995 and 2017 are obtained from the Atlas of Economic Complexity.

Data on the bilateral real exchange rate between Japan and the importing countries are obtained from the CEPII-CHELEM database. The exchange rate is defined so that an increase represents an appreciation of the Japanese yen. Data on real GDP in importing countries come from the CEPII gravity database.[§§]

Table 4 reports exchange rate elasticities for individual categories of chemical exports. It indicates that 39 are significant at the 5 percent level and 4 more at the 10 percent level. The average value of the elasticities across all 93 categories is -0.05, which is close to the elasticity of -0.11 that Thorbecke and Salike (2020) reported for aggregate chemical exports. The results in Table 4 indicate though that the aggregate elasticity value masks considerable variablity in elasticities across individual categories.

[§§] The website for the gravity database is http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=8.

Many of the elasticities are negative, implying that an appreciation of the yen reduces exports for these categories. Some are positive. How can we understand positive elasticities? Some chemical exports, such as those associated with the petroleum industry, are denominated in U.S. dollars (Eurostat, 2019). An appreciation of the yen is often associated with a depreciation of the U.S. dollar. When the dollar depreciates, the prices of exports denominated in dollars in terms of the importing countries' currencies decrease and they import more. Thus an appreciation of the yen can be associated with an increase in exports for these goods.

Is there a relationship between price elasticities and product complexity values? Regressing real exchange rate elasticities across products ($\beta_{1,i,brer}$) on the corresponding PCI rankings (PCI_i) yields[***]:

$$\beta_{1,i,brer} = \underset{(0.148)}{0.235} - \underset{(0.000284)}{0.000740} PCI_i \qquad (7)$$

Adjusted R-squared = 0.0372, Standard error of regression = 0.850, Heteroscedasticity and autocorrelation consistent standard errors in parentheses.

The coefficient on the PCI ranking equals -0.000740 and the corresponding p-value (two-tailed test) equals 0.01. The coefficient is of the expected sign. Its value implies that a chemical category with a ranking one standard deviation below the mean ranking for chemical exports has on average an elasticity that is 19 basis points less negative.

The important implication of the findings in equation (7) is that exports of more ubiquitous chemicals decrease more in response to exchange rate appreciations than exports of sophisticated chemicals. These findings parallel the findings of Arbatli and Hong (2016) using a very different dataset.

[***] We exclude the elasticity on phosphides excluding pherophosphorous (HS 2848) because the elasticity is implausibly large (3.152). This could be because the sample size for this category is small (326). Results including the elasticity on phosphides excluding pherophosphorous, available on request, are very similar.

Is there also an association between product complexity and countries' GDPs? We might expect sophisticated products to flow disproportionately to countries with higher incomes and ubiquitous products to flow to all countries. To test for this we regress GDP coefficients across products ($\beta_{2,i,Y}$) on the corresponding PCI rankings (PCI_i):

$$\beta_{2,i,Y} = \underset{(0.177)}{1.702} - \underset{(0.00046)}{0.00126} PCI_i \qquad (8)$$

Adjusted R-squared = 0.0593, Standard error of regression = 1.178, Heteroscedasticity and autocorrelation consistent standard errors in parentheses.

The coefficient on the PCI ranking equals -0.00126 and the corresponding p-value (two-tailed test) equals 0.01. The coefficient is of the expected sign. Its value implies that a chemical category with a ranking one standard deviation below the mean ranking for chemical exports has on average a coefficient on GDP that is 32 basis points larger. Thus higher levels of GDP in the importing countries are associated with more imports of sophisticated chemical goods.

The important implication of the findings in equation (8) is that more sophisticated products tend to flow to wealthier countries. This would benefit producers of complex goods if richer countries provide a more stable source of demand than poorer countries.

4. Conclusion

Exchange rate swings can exert first order effects on exporting firms. Appreciations can reduce exporters' profitability by decreasing profit margins (if the appreciation is not passed through to higher prices abroad) or by lowering sales (if the appreciation is passed through to higher retail prices abroad).

This paper uses highly disaggregated data from the Japanese chemical industry to examine whether exchange rates affect different types of products differently. Focusing on exports from a single industry within a single country helps to control for other factors that could interfere with inference.

We find that yen appreciations reduce the stock prices of chemical companies linked to downstream industries facing heavy competition abroad such as automobiles and electronic parts and components. This makes sense since the profitability of these downstream industries plummets when the yen appreciates (see, e.g., Nguyen and Sato, 2019, and Thorbecke, 2019).

We than investigate whether exports depend on product complexity. Researchers at the International Monetary Fund, the Asian Development Bank, and elsewhere have highlighted product complexity as a factor influencing trade elasticities. They posited that complex products are less substitutable in international trade and should have lower elasticities. Arbatli and Hong (2016) employed Hidalgo and Hausmann's (2009) quantitative measure of product complexity to measure sophistication. They reported that exports of more sophisticated goods from Singapore decreased less then exports of ubiquitous goods when exchange rates appreciated.

We investigate the relationship between PCIs and elasticities for the Japanese chemical industry. We obtain PCI values for 93 categories of chemical exports at the HS 4-digit level. Regression results indicate wide variation in price elasticities for individual chemical exports and a strong relationship between more sophisticated goods and smaller drops in exports when the yen appreciates. The results also indicate that more advanced goods flow to higher income countries.

These findings provide several directions for future research. First, trade wars, tariffs, exchange rate swings, and other factors impact trade prices and trade flows. The results presented here indicate that upgrading industrial structure and exporting more sophisticated products may provide a way to reduce profit and export volatility arising from these factors. Researchers should continue to investigate this issue. Second, the results indicate that more sophisticated products flow to wealthier countries. If demand from wealthier countries is more stable than demand from poorer countries, then exporting to richer countries can help to stabilize business cycle fluctuations. Scholars should continue investigating whether more sophisticated products flow disproportionately to wealthier countries and whether import demand by wealthier countries is more stable than import demand by poorer countries. Finally, Orcutt (1950) showed that aggregate estimates of trade elasticities are biased downwards. To reduce this bias authors sometimes disaggregate exports into categories such as transport equipment or chemicals. In this paper, we disaggregate chemical exports further into 93 individual types and find huge variation in elasticities. Researchers should continue exploring the rich cross-sectional information contained in highly disaggregated product elasticities.

The findings reported here also have implications for firms and policy makers. Upstream firms should diversify the downstream industries they supply to. If they focus on a single industry like electronic parts and components, then exchange rate appreciations such as occurred with the yen between 2007 and 2012 can devastate downstream firms and their upstream suppliers. Firms should also invest in research and development (R&D), especially during the good times, so that they can innovate and produce differentiated products. Governments should encourage R&D by easing firms' tax burdens. They should also nurture creativity by providing future engineers and scientists not just technical training but also a broad education that includes literature, history, and philosophy (Sawa, 2013). Finally, firms and governments should encourage cross cultural collaboration to develop cutting edge ideas and foster discoveries (Berliant and Fujita, 2012).

Table 1. The Exposure of Japanese Chemical Firms to Macroeconomic Variables

Company	Exposure to yen/dollar exchange rate	Standard Error	Exposure to Japanese Stock Market	Standard Error	Exposure to World Stock Market	Standard Error	Exposure to Crude Oil Price	Standard Error
ADEKA	0.0177	0.0431	0.9138***	0.0276	0.0035	0.0278	-0.0076	0.008
AIR WATER	0.0624	0.0446	0.8992***	0.0258	-0.0055	0.032	-0.0084	0.0104
ASAHI KASEI	-0.0178	0.0442	1.0807***	0.0295	0.038	0.0302	0.0053	0.0093
C UYEMURA & COMPANY	0.0162	0.0656	0.3852***	0.0442	0.0193	0.0431	0.0269	0.014
DAICEL	0.1362***	0.0522	1.0027***	0.0312	0.0757**	0.0363	0.0017	0.0113
DENKA	0.1152	0.0476	1.11***	0.0286	0.0489	0.0336	0.0187	0.015
DIC	0.0287	0.0535	1.1106***	0.0404	0.0398	0.0385	0.0151	0.0109
EARTH	-0.0689	0.0399	0.5359***	0.0269	-0.0008	0.0289	-0.0239	0.0125
FUJIMI	0.0803*	0.0643	0.8894***	0.0399	0.0002	0.0527	0.0175	0.0138
FUSO CHEMICAL	0.0256	0.0681	0.526***	0.0514	0.002	0.0515	0.0238	0.015
INABATA & COMPANY	0.0466	0.0459	0.9966***	0.0334	-0.0272	0.0373	-0.0028	0.0105
J S R	0.0898	0.0584	1.0625***	0.0294	0.0931**	0.0409	0.0076	0.0111
JCU	-0.0862	0.0726	0.8141***	0.0684	-0.0832	0.0604	0.0268	0.0188
KANEKA	0.017	0.0492	0.9908***	0.0315	0.0404	0.0336	0.0023	0.0107
KH NEOCHEM	-0.1773	0.1568	1.1965***	0.1085	0.0497	0.0769	0.0528	0.0337
KONISHI	0.038	0.0565	0.7172***	0.0322	-0.0159	0.0387	0.0073	0.0119
KUMIAI CHEMICAL IND.	0.0319	0.0608	1.0076***	0.0419	-0.02	0.0443	0.0042	0.014
KURARAY	0.1389***	0.0457	0.9354***	0.0307	0.065**	0.0323	-0.008	0.0111
LINTEC	0.121**	0.051	0.9034***	0.031	-0.0324	0.0331	0.0196**	0.0096
MITSUBISHI CHM.HDG.	0.1053*	0.0573	1.1015***	0.0363	0.1199**	0.0481	-0.0296*	0.0154
MITSUBISHI GAS CHM.	0.0742	0.0593	1.1739***	0.04	0.0421	0.0385	0.0141	0.0134
MITSUI CHEMICALS	0.0455	0.0558	1.1754***	0.0374	0.0862**	0.0359	-0.0116	0.0122
NAGASE	0.0084	0.0433	0.9901***	0.028	-0.0539***	0.0258	-0.0035	0.0103
NIPPON KAYAKU	0.094**	0.0432	1.0085***	0.0339	0.019	0.0283	0.009	0.0096
NIPPON SHOKUBAI	-0.0829*	0.0456	0.9349***	0.0286	0.026	0.0293	0.0104	0.0109
NIPPON SODA	0.1546***	0.0599	1.2031***	0.0388	0.0917**	0.0403	-0.0095	0.0132
NISSAN CHEMICAL	0.0622	0.0509	1.0932***	0.0304	0.1432***	0.0374	0.0045	0.0103
NITTO DENKO	0.0768	0.0594	1.0884***	0.0321	0.0784*	0.0401	-0.0077	0.015
NOF	0.001	0.0443	0.948***	0.0314	-0.0309	0.0367	0.0098	0.0106
OSAKA SODA	0.0457	0.0542	0.7036***	0.042	-0.0425	0.0413	-0.0087	0.014
SANYO CHEMICAL INDS.	0.0572	0.0459	0.8386***	0.0399	-0.0006	0.0338	-0.0062	0.0099
SHIN-ETSU CHEMICAL	0.08*	0.0442	1.1168***	0.0268	0.09**	0.0292	-0.0069	0.0085
SHIN-ETSU POLYMER	0.0141	0.0467	0.9709***	0.0313	0.048	0.0329	0.0115	0.0111
SHOWA DENKO KK	0.0859	0.0543	1.1251***	0.0351	0.0567	0.0365	0.0016	0.0119
SUMITOMO BAKELITE	-0.0147	0.0482	1.0425***	0.027	-0.0246	0.0324	0.019	0.0114
SUMITOMO CHEMICAL	0.1173**	0.0537	1.1813***	0.0291	0.0907***	0.0308	-0.0031	0.0125
T HASEGAWA	0.0589	0.0434	0.7594***	0.0343	0.017	0.032	0.0136	0.01
TAIYO HOLDINGS	0.074	0.0522	0.8439***	0.0314	-0.0029	0.0355	-0.0068	0.0126

TAIYO NIPPON SANSO	-0.0384	0.0561	1.0772***	0.0308	-0.0004	0.0367	0.0045	0.0116
TAKI CHEMICAL	-0.0591	0.059	0.3694***	0.0394	-0.0118	0.0476	-0.0069	0.0169
TEIJIN	0.0116	0.0511	1.0115***	0.0334	0.0587*	0.0326	0.0043	0.0102
TOAGOSEI	0.0506	0.0437	1.0483***	0.0284	0.0155	0.0351	-0.0045	0.0121
TOKAI CARBON	0.2261***	0.0626	1.1928***	0.039	0.0714	0.0564	0.0157	0.015
TOKUYAMA	0.0289	0.0676	1.1804***	0.0387	0.0604	0.0414	-0.0106	0.0152
TORAY INDS.	-0.0407	0.0437	0.9863***	0.0306	0.1017***	0.0323	0.0001	0.0093
TOSOH	0.1691***	0.0564	1.1821***	0.0286	0.1647***	0.0404	0.0019	0.0123
TOYO GOSEI	-0.1508*	0.0873	0.7074***	0.0666	-0.0045	0.0652	0	0.0247
TOYOBO	0.0218	0.0552	0.9509***	0.0444	0.0304	0.0373	0.0061	0.0097
TRI CHEMICAL LABS.	-0.0345	0.1372	0.818***	0.0918	0.1661*	0.0979	0.0222	0.0346
UBE INDUSTRIES	-0.0496	0.0584	1.1854***	0.0293	0.0278	0.0372	0.0127	0.0122
ZEON	0.0402	0.0615	1.1773***	0.0359	0.0355	0.0354	-0.0058	0.0115

Source: Datastream database and calculations by the author.
Note: The coefficients come from a regression of stock returns for each chemical firm on the change in the yen/dollar exchange rate, the return on the Japanese stock market, the return on the world stock market, and the change in the log of the spot price for Dubai crude oil. Daily data over the 4 September 2000 to 20 September 2020 are used. There are 5150 observations. In some cases data are unavailable starting on 4 September 2000. In those cases, data are used from the first date they are available. Heteroskedasticity and autocorrelation consistent standard errors are reported.
*** (**)[*] denotes significance at the 1% (5%) [10%] level.

Table 2. Coefficients from Regressions of Returns on Japanese Chemical Firms on Returns on Downstream Industries

Chemical Firm	Downstream Industries												
	Automobile	Biotechnology	Cement	Construction	Cosmetics	Electronic parts and components	Fertilizer	Food	Glass	Healthcare	Pharmaceuticals	Plastics	Semiconductors
ADEKA	-0.080*** (0.032)	NSS	NSS	0.055* (0.032)	NSS	0.090** (0.037)	0.053*** (0.016)	NSS	0.031* (0.019)	NSS	NSS	0.242*** (0.028)	NSS
AIR WATER	NSS	NSS	NSS	NSS	NSS	0.128*** (0.034)	0.033*** (0.011)	0.182*** (0,042)	0.034* (0.018)	0.224* (0.013)	-0.213** (0.017)	0.132*** (0.028)	NSS
ASAHI KASEI	NSS	NSS	NSS	NSS	-0.056*** (0.022)	0.121*** (0.038)	NSS	0.076* (0.045)	0.046*** (0.018)	NSS	NSS	0.115*** (0.028)	NSS
C UYEMURA & COMPANY	NSS	0.026* (0.016)	NSS	NSS	NSS	NSS	0.040** (0.018)	-0.117* (0.057)	NSS	0.414** (0.201)	-0.363** (0.164)	0.064* (0.037)	NSS
DAICEL	NSS	NSS	NSS	NSS	NSS	0.244*** (0.043)	0.034** (0.016)	NSS	NSS	NSS	NSS	0.138*** (0.037)	NSS
DENKA	NSS	NSS	0.033** (0.016)	NSS	-0.077*** (0.025)	0.242*** (0.038)	0.023* (0.013)	NSS	0.054** (0.022)	NSS	NSS	0.153*** (0.025)	NSS
DIC	NSS	NSS	0.068*** (0.023)	NSS	-0.085*** (0.029)	NSS	0.070*** (0.016)	-0.086* (0.050)	NSS	0.303* (0.167)	-0.280** (0.135)	0.171*** (0.032)	NSS
EARTH	-0.068** (0.032)	0.018* (0.010)	NSS	NSS	0.097*** (0.020)	NSS	0.026*** (0.009)	0.218*** (0.043)	0.033* (0.019)	NSS	NSS	0.099*** (0.022)	NSS
FUJIMI	NSS	NSS	NSS	0.080* (0.042)	0.077** (0.036)	0.295*** (0.063)	0.031** (0.015)	0.139** (0.068)	0.055** (0.028)	NSS	NSS	0.155** (0.045)	0.137*** (0.037)
FUSO CHEMICAL	NSS	0.060*** (0.016)	NSS	NSS	NSS	NSS	0.046** (0.021)	NSS	NSS	0.381* (0.228)	NSS	0.132** (0.046)	0.090** (0.037)
INABATA & COMPANY	NSS	NSS	NSS	0.087** (0.039)	-0.043* (0.024)	0.086** (0.038)	0.06*** (0.014)	NSS	NSS	NSS	NSS	0.156*** (0.028)	NSS
J S R	NSS	NSS	NSS	-0.091*** (0.031)	NSS	0.319*** (0.050)	0.041*** (0.013)	-0.094** (0.043)	0.068*** (0.022)	0.350*** (0.187)	-0.369** (0.161)	0.093*** (0.030)	0.096*** (0.030)
JCU	-0.144** (0.060)	0.066*** (0.020)	NSS	NSS	0.063* (0.033)	NSS	0.050*** (0.17)	NSS	NSS	NSS	NSS	0.144*** (0.050)	NSS
KANEKA	NSS	NSS	NSS	NSS	NSS	0.183*** (0.038)	0.030*** (0.011)	NSS	0.060*** (0.017)	NSS	0.234* (0.140)	0.148*** (0.027)	NSS
KH NEOCHEM	-0.313** (0.132)	NSS	NSS	0.242* (0.138)	0.131** (0.067)	NSS	NSS	-0.336** (0.1520	NSS	NSS	NSS	0.347*** (0.116)	NSS
KONISHI	NSS	NSS	NSS	0.096*** (0.034)	NSS	NSS	NSS	0.284*** (0.049)	NSS	NSS	NSS	0.167*** (0.030)	0.077*** (0.028)
KUMIAI CHEMICAL IND.	NSS	NSS	NSS	NSS	NSS	NSS	0.999*** (3.07E-05)	NSS	-8.66E-05* (4.74E-05)	NSS	NSS	NSS	0.000106* (6.07E-05)
KURARAY	0.096*** (0.032)	NSS	NSS	NSS	NSS	0.134*** (0.037)	0.025** (0.013)	NSS	0.08*** (0.024)	0.52*** (0.187)	-0.369** (0.159)	0.089*** (0.029)	NSS
LINTEC	NSS	NSS	NSS	NSS	NSS	0.190*** (0.039)	0.036*** (0.015)	0.079* (0.048)	0.054**	NSS	NSS	0.135*** (0.028)	0.0468* (0.028)
MITSU-BISHI CHM.HDG.	0.101*** (0.039)	-0.024** (0.012)	NSS	-0.071** (0.034)	NSS	0.131*** (0.040)	0.036*** (0.014)	NSS	0.063*** (0.023)	NSS	NSS	0.107*** (0.028)	0.070*** (0.025)
MITSU-BISHI GAS CHM.	NSS	NSS	NSS	NSS	NSS	0.217*** (0.052)	0.031** (0.014)	-0.175*** (0.054)	0.082*** (0.029)	-0.419** (0.191)	0.272* (0.156)	0.151*** (0.033)	NSS
MITSUI CHEM-ICALS	0.079* (0.042)	NSS	0.056*** (0.019)	NSS	NSS	0.209*** (0.048)	NSS	NSS	0.069** (0.029)	NSS	NSS	0.129*** (0.035)	NSS
NAGASE	NSS	NSS	NSS	NSS	NSS	0.073** (0.033)	NSS	0.168*** (0.045)	NSS	NSS	NSS	0.164*** (0.023)	NSS
NIPPON KAYAKU	NSS	-0.023** (0.009)	0.035** (0.015)	0.038* (0.022)	-0.066*** (0.024)	0.105*** (0.040)	NSS	0.221*** (0.046)	0.043** (0.019)	NSS	NSS	0.101*** (0.032)	0.056** (0.028)
NIPPON SHOKUBAI	NSS	0.026*** (0.009)	NSS	0.068** (0.034)	NSS	0.121*** (0.040)	0.043*** (0.012)	NSS	NSS	NSS	-0.293** (0.134)	0.129*** (0.029)	NSS
NIPPON SODA	NSS	NSS	0.099*** (0.025)	NSS	NSS	0.172*** (0.054)	0.075*** (0.016)	NSS	0.069*** (0.023)	NSS	NSS	0.158*** (0.036)	0.055* (0.031)
NISSAN CHEMICAL	NSS	-0.020* (0.011)	0.033* (0.018)	NSS	NSS	0.279*** (0.045)	NSS	0.138*** (0.051)	0.062*** (0.022)	0.572*** (0.197)	-0.407** (0.168)	0.101*** (0.031)	0.066** (0.030)
NITTO DENKO	NSS	NSS	NSS	-0.078** (0.037)	NSS	0.416*** (0.063)	0.034** (0.014)	-0.128*** (0.047)	0.083*** (0.028)	NSS	NSS	NSS	0.149*** (0.033)
NOF	-0.123*** (0.035)	0.019** (0.093)	NSS	NSS	NSS	0.144*** (0.040)	0.049*** (0.012)	0.098** (0.048)	NSS	0.386*** (0.143)	-0.271** (0.016)	0.175*** (0.025)	-0.058*** (0.022)
OSAKA SODA	NSS	0.031* (0.016)	NSS	NSS	NSS	NSS	0.035** (0.018)	0.152*** (0.053)	NSS	NSS	NSS	0.208*** (0.039)	NSS
SANYO CHEMICAL INDS.	NSS	0.018* (0.010)	NSS	0.059* (0.036)	0.049** (0.024)	0.127*** (0.040)	0.060*** (0.011)	0.105** (0.045)	NSS	NSS	NSS	0.214*** (0.032)	NSS
SHIN-ETSU CHEMICAL	NSS	-0.040*** (0.009)	NSS	NSS	NSS	0.186*** (0.040)	NSS	NSS	0.052*** (0.019)	NSS	NSS	NSS	0.210*** (0.025)
SHIN-ETSU POLYMER	NSS	0.025** (0.011)	NSS	NSS	NSS	0.157*** (0.043)	0.041*** (0.014)	NSS	NSS	NSS	NSS	0.261*** (0.031)	0.113*** (0.029)
SHOWA DENKO KK	NSS	NSS	0.078*** (0.020)	NSS	0.064** (0.030)	0.305*** (0.045)	0.066*** (0.015)	-0.198*** (0.057)	0.073*** (0.022)	NSS	NSS	0.160*** (0.036)	0.068** (0.034)
SUMITOMO BAKELITE	NSS	NSS	NSS	NSS	NSS	0.228*** (0.046)	NSS	NSS	0.084*** (0.019)	NSS	NSS	0.162*** (0.027)	0.223*** (0.031)
SUMITOMO CHEMICAL	NSS	-0.024** (0.010)	0.048** (0.020)	-0.086 (0.030)	NSS	0.175*** (0.048)	0.024* (0.014)	-0.147*** (0.050)	0.070*** (0.026)	NSS	NSS	0.098*** (0.025)	0.066** (0.026)
T HASEGAWA	NSS	NSS	NSS	NSS	NSS	0.066* (0.039)	NSS	0.255*** (0.044)	NSS	NSS	NSS	0.171*** (0.027)	NSS

TAIYO HOLDINGS	NSS	NSS	NSS	NSS	NSS	0.187*** (0.044)	0.027* (0.014)	NSS	NSS	NSS	NSS	0.131*** (0.030)	NSS
TAIYO NIPPON SANSO	NSS	NSS	NSS	NSS	NSS	0.181*** (0.053)	NSS	NSS	NSS	NSS	NSS	0.131*** (0.035)	NSS
TAKI CHEMICAL	-0.097** (0.045)	NSS	NSS	NSS	NSS	NSS	NSS	NSS	NSS	NSS	NSS	0.084** (0.036)	NSS
TEIJIN	NSS	NSS	0.029* (0.016)	NSS	NSS	0.113** (0.049)	0.032*** (0.011)	NSS	0.033* (0.018)	-0.392** (0.167)	0.269* (0.143)	0.089*** (0.028)	NSS
TOAGOSEI	NSS	NSS	0.043* (0.023)	NSS	NSS	0.131*** (0.043)	0.053*** (0.015)	0.197*** (0.047)	NSS	NSS	NSS	0.204*** (0.027)	NSS
TOKAI CARBON	NSS	0.024* (0.013)	0.107*** (0.022)	NSS	NSS	0.362*** (0.055)	0.039** (0.017)	NSS	0.108*** (0.031)	NSS	-0.410** (0.016)	0.099** (0.042)	0.088** (0.039)
TOKUYAMA	-0.102* (0.054)	NSS	0.089*** (0.027)	NSS	NSS	0.220** (0.086)	0.036** (0.015)	NSS	0.101*** (0.031)	NSS	NSS	0.227*** (0.048)	0.129*** (0.038)
TORAY INDS.	-0.066** (0.031)	NSS	0.028* (0.017)	0.063** (0.030)	NSS	0.123*** (0.034)	NSS	NSS	NSS	NSS	NSS	0.067*** (0.026)	NSS
TOSOH	NSS	NSS	0.083*** (0.021)	NSS	NSS	0.160*** (0.049)	0.039** (0.016)	NSS	0.107*** (0.025)	NSS	NSS	0.105*** (0.031)	0.121*** (0.030)
TOYO GOSEI	-0.147** (0.067)	0.064*** (0.019)	NSS	NSS	NSS	NSS	0.036* (0.021)	NSS	NSS	0.739*** (0.263)	-0.426** (0.216)	0.121** (0.053)	0.139*** (0.054)
TOYOBO	NSS	0.019* (0.011)	0.059*** (0.019)	0.124*** (0.034)	NSS	NSS	NSS	NSS	NSS	NSS	NSS	0.100*** (0.038)	NSS
TRI CHEMICAL LABS.	-0.283** (0.120)	0.231*** (0.036)	NSS	NSS	NSS	NSS	NSS	NSS	NSS	NSS	NSS	0.243*** (0.068)	0.324*** (0.071)
UBE INDUSTRIES	NSS	NSS	0.158*** (0.027)	NSS	NSS	0.131*** (0.044)	0.033** (0.014)	-0.147*** (0.050)	0.055** (0.026)	NSS	NSS	0.112*** (0.028)	0.050* (0.029)
ZEON	NSS	NSS	0.077*** (0.023)	NSS	-0.064*** (0.024)	0.274*** (0.050)	0.061*** (0.015)	NSS	0.050* (0.026)	NSS	NSS	0.147*** (0.030)	0.087*** (0.031)

Source: Datastream database and calculations by the author.
Note: The coefficients come from a regression of stock returns for each chemical firm on the returns on the Japanese stock market and the following industries automobiles, biotechnology, cement, construction, cosmetics, electronic parts and components, fertilizer, food, glass, healthcare, pharmaceuticals, plastics, and semiconductors. Daily data over the 26 September 2002 to 29 May 2020 are used. There are 4612 observations. In some cases data are unavailable starting on 26 September 2002. In those cases, data are used from the first date they are available. NSS indicates that the coefficient is not statistically significant at at least the 10% level. Heteroskedasticity and autocorrelation consistent standard errors are reported.
*** (**)[*] denotes significance at the 1% (5%) [10%] level.

Table 3. The Relationship between Chemical Firms' Exchange Rate Betas and Industry Betas

Industry	Regression Coefficient	Standard Error
Automobiles	0.398**	0.169
Biotechnology	0.111	0.327
Cement	0.122	0.356
Construction	-0.187	0.237
Cosmetics	-0.127	0.186
Electronic Parts and Components	0.228**	0.102
Fertilizer	0.096***	0.020
Food	0.161**	0.061
Glass	0.710	0.452
Healthcare	-0.007	0.143
Pharmaceutical	-0.049	0.184
Plastics	0.218**	0.092
Semiconductors	0.006	0.148

Source: Calculations by the author.
Note: The coefficients come from a regression of the exchange rate betas for the 51 chemical firms reported in Table 1 on the regression coefficients for 13 downstream industries from regressions of returns on each of the 51 firms on returns on the aggregate Japanese market and returns on the following industries: automobiles, biotechnology, cement, construction, cosmetics, electronic parts and components, fertilizer, food, glass, healthcare, pharmaceuticals, plastics, and semiconductors. There are 51 observations. Heteroskedasticity and autocorrelation consistent standard errors are reported.
*** (**) denotes significance at the 1% (5%) level.

Table 4. Elasticity Estimates for Individual Chemical Exports from Japan.

HS Code	Product	Average PCI Ranking	Coefficient on Real Exchange Rate	t-statistic	Coefficient on Real GDP in Importing Countries	t-statistic	Adjusted R-squared
2801	Fluorine, Chlorine, Bromine, Iodine	897.8	-0.388	-1.12	0.942**	2.48	0.8402
2802	Sulphur	798.3	-2.608***	-4.57	-3.935***	-6.62	0.7105
2803	Carbon	609.8	0.024	0.07	1.1***	3.21	0.7798
2804	Hydrogen, Rare gases	696.3	0.512	1.57	1.584***	4.41	0.7937
2805	Alkalai, Rare earth metals, Mercury	718.3	-1.348***	-2.88	1.732***	3.51	0.5957
2806	Hydrogen chloride, Chlorosulfuric acid	668.0	0.563	1.05	2.506***	4.56	0.7659
2807	Sulfuric acid, Oleum	755.1	-1.037**	-2.02	1.7***	2.83	0.7879
2808	Nitric acid	566.6	1.435***	3.16	2.302***	5.03	0.8082
2809	Diphosphorus pentoxide, Phosphoric acid	762.5	-1.168***	-2.71	3.706***	7.4	0.8
2810	Oxides of boron	839.9	-0.89**	-2.31	-0.442	-1.05	0.7462
2811	Other inorganic acids	517.4	-0.027	-0.12	0.294	1.19	0.8578
2812	Halides of non-metals	113.8	0.093	0.24	3.304***	7.07	0.7424
2813	Sulphides of non-metals	377.9	1.059	1.03	1.402	1.09	0.5231
2814	Ammonia	1019.6	0.359	0.72	1.227***	2.22	0.7856
2815	Sodium hydroxide, Potassium hydroxide	621.7	-1.97***	-4.63	0.852*	1.86	0.7990
2816	Hydroxide and peroxide of magnesium, strontium, or barium	218.1	0.347	0.96	2.191***	6.16	0.7711
2817	Zinc	662.2	0.662*	1.76	0.191	0.48	0.7228
2818	Aluminum oxide, Aluminum peroxide	930.0	-0.304	-1.21	0.562**	2.06	0.8228
2819	Chromium oxide	597.2	-0.265	-0.65	3.228***	7.04	0.6981
2820	Manganese oxide	720.8	-2.03***	-4.05	-1.51***	-2.89	0.5965
2821	Iron oxide and hydroxide	407.2	-0.082	-0.23	1.667***	4.24	0.7994
2822	Cobalt oxide and hydroxide	497.7	-0.734	-1.23	0.271	0.45	0.6180
2823	Titanium oxide	316.9	-0.228	-0.85	1.37***	4.37	0.7735
2824	Lead oxide	821.4	-0.46	-0.69	-1.756***	-2.66	0.5274

2825	Hydrazine and Hydroxylaime	705.5	0.104	0.36	0.831**	2.49	0.8127
2826	Fluorides	529.7	2.013***	6.06	2.793***	7.34	0.7753
2827	Chlorides, Bromides, and Iodines	407.8	0.645**	2.51	0.249	0.84	0.8058
2828	Hypochlorites, Hypobromites	880.9	-0.789***	-3.27	1.000***	3.67	0.7442
2829	Chlorates, Bromates, Iodates, Periodates	567.4	-0.539	-1.18	0.847*	1.71	0.6555
2830	Sulphides	632.3	0.762*	1.71	2.171***	4.62	0.6694
2831	Dithionites, Sulphoxylates	505.1	0.074	0.1	0.285	0.49	0.5323
2832	Sulphites, Thiosulfates	699.8	-0.085	-0.24	0.199	0.52	0.7675
2833	Sulfates, Alums	783.9	-0.915***	-3.60	0.077	0.27	0.8458
2834	Nitrites, Nitrates	755.0	-0.475	-1.19	2.129***	4.72	0.7741
2835	Phosphonates, Phosphinates, Phosphates	588.9	-0.111	-0.37	-0.527	-1.53	0.7738
2836	Carbonates	684.4	-0.174	-0.69	0.888***	3.17	0.7928
2837	Cyanides	536.6	-0.407	-0.8	0.671	1.11	0.7109
2838	Fulminates, Cyanates, and Thiocyanates	376.0	-2.614***	-3.25	-1.415	-1.02	0.6968
2839	Silicates	692.4	-0.896***	-2.73	-1.262***	-3.36	0.7108
2840	Borates	478.6	0.844**	2.14	1.053**	2.4	0.6813
2841	Salts of Oxometallic Acid	713.6	0.721**	1.98	1.566***	3.74	0.7638
2842	Salts of peroxoacid or inorganic acid	271.6	-0.016	-0.05	1.711***	4.84	0.7552
2843	Colloidal precious metals, Compounds of precious metals	256.8	0.118	0.26	1.545***	3.52	0.8133
2844	Radioactive chemical elements and isotopes	706.9	-0.564	-1.14	1.601***	3.05	0.6595
2845	Other isotopes	349.9	1.652**	2.05	-0.341	-0.48	0.4794
2846	Rare metal compounds	422.9	0.526	1.19	1.615***	3.54	0.7348
2847	Hydrogen peroxide	392.0	1.113**	2.09	2.892***	5.24	0.7953
2848	Phosphides excluding pherophosphorous	540.4	3.152***	4.58	3.744***	5.69	0.5723
2849	Carbides	493.7	-0.756**	-2.08	-0.581	-1.56	0.7064
2850	Hydrides, Azides, Nitrides, Silicides, Borides	95.2	-0.569	-1.6	0.852**	2.23	0.7377
2851	Other inorganic compounds and Liquid air	223.7	0.969**	2.52	2.439***	6.01	0.6988

2901	Acyclic hydrocarbons	627.5	1.159***	2.78	1.849***	3.95	0.8013
2902	Cyclic hydrocarbons	519.6	-0.515	-1.35	0.674	1.54	0.7778
2903	Halogenated derivatives of hydrocarbons	330.7	-0.057	-0.22	2.218***	8.09	0.8365
2904	Sulfanated, nitrated, or nitrosated derivatives of hydrocarbons	613.7	-0.067	-0.19	0.714*	1.77	0.7555
2905	Acyclic alcohols	779.7	-0.346	-1.51	1.034***	3.71	0.8672
2906	Cyclic alcohols	234.7	0.288	0.98	2.404***	6.87	0.7894
2907	Phenols	75.8	-0.708**	-2.66	2.37***	6.77	0.8316
2908	Phenol derivatives	222.2	0.979**	2.55	2.43***	5.85	0.802
2909	Ethers and Peroxides	522.8	0.065	0.23	0.179	0.57	0.8409
2910	Epoxides, Epoxyalcohols, and Epoxyphenols	122.4	-0.563	-1.49	0.719	1.64	0.7735
2911	Acetals and Hemiacetals and Derivatives	220.6	-0.483	-1.06	1.218**	2.60	0.5976
2912	Aldehydes, Peroformaldehyde	185.2	0.578**	2.09	1.482***	4.62	0.8491
2913	Halogenated, Sulfonated, Nitrated, and Nitrosated derivatives of HS 2912	70.4	1.824***	2.94	2.091***	3.59	0.6658
2914	Ketones and Quinones	104.8	-0.228	-0.94	2.012***	6.92	0.8437
2915	Saturated acyclic monocarbonxylic acids and their derivatives	200.7	-0.408**	-2.02	0.385	1.61	0.867
2916	Unsaturated acyclic monocarbonxylic acids and their derivatives	148.3	-0.174	-0.93	1.737***	6.78	0.8459
2917	Polycarbonxylic acids and their derivatives	464.0	-1.58***	-5.3	0.25	0.7	0.8132
2918	Carbonxylic acids with additional oxygen functions and their derivatives	343.7	0.098	0.46	1.138***	4.35	0.8435
2919	Esters, phosphoric and their salts	121.4	0.677**	1.98	0.962**	2.57	0.7842
2920	Other Esters	105.7	0.018	0.06	0.699*	1.93	0.7684
2921	Amine function compounds	126.5	1.063***	4.66	1.159***	4.25	0.8634
2922	Oxygen function amino compounds	396.2	-0.2	-0.93	0.954***	3.61	0.8396

2923	Quatenary ammonium salts and Hydroxides	193.7	-0.13	-0.42	2.124***	6.03	0.8052
2924	Carboxyamide function compounds, Amide function compounds	269.2	0.837***	3.38	1.359***	4.29	0.8201
2925	Carboxyamide function compounds, Imine function compounds	94.7	-0.439*	-1.84	0.91***	2.81	0.7973
2926	Nitrile function compounds	186.2	0.544	1.46	0.326	0.74	0.7762
2927	Diazo-, azo-, or azoxy-compounds	387.8	1.066***	3.6	1.958***	5.68	0.8011
2928	Organic derivatives of hydrazine or hydroxylamine	218.8	-1.05***	-3.51	2.01***	5.54	0.7415
2929	Other nitrogen function compounds	155.1	-1.085***	-4.84	1.914***	8.15	0.7527
2930	Organo-sulfur compounds	80.1	-0.489**	-2.16	1.487***	5.23	0.7938
2931	Other organo-inorganic compounds	83.7	-0.622**	-2.2	0.737**	2.34	0.7744
2932	Heterocyclic compounds with oxygen hetero atoms	248.0	0.234	0.82	2.578**	7.34	0.8226
2933	Heterocyclic compounds with nitrogen hetero atoms	128.8	-0.035	-0.18	0.68***	2.92	0.874
2934	Nucleic acids	33.0	-0.299	-1.19	0.442	1.39	0.82
2935	Sulphonamides	130.4	-0.033	-0.07	0.567	1.06	0.6186
2936	Provitamins, Vitamins	242.8	-0.101	-0.47	2.178***	7.92	0.8243
2937	Hormones	46.4	1.059**	2.17	2.381***	4.37	0.6112
2938	Glycocides	553.9	-0.826**	-2.37	0.42	1.08	0.7293
2939	Alkaloids	423.3	-0.89*	-1.77	0.446	0.86	0.6214
2940	Sugars other than sucrose, lactose, maltose, glucose, and fructose	204.1	0.224	0.72	2.861***	8.00	0.7669
2941	Antibiotics	288.0	-0.475	-1.58	0.241	0.63	0.7892
2942	Other organic compounds	681.7	0.902**	2.1	1.354***	3.26	0.6906

Notes: The table presents trade elasticities for Japanese chemical exports. The regressions include time and importer-product fixed effects. HS code is the Harmonized System 4-digit code. Average PCI ranking is the average rank of the product over the 1995-2017 period relative to 1242 goods according to the Product Complexity Index of Hausmann and Hidalgo (2009). ***[**] (*) denotes significance at the 1% [5%] (10%) level.

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