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***At the time of circulation of this paper to the Board, the authorities have indicated that they need more time to consider whether they will consent to the Fund's publication of this paper. Publication will only proceed upon the receipt by the Fund of the member's explicit consent.**

INTERNATIONAL MONETARY FUND

SINGAPORE

SELECTED ISSUES

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Approved By
Alex Mourmouras

Prepared By Asia and Pacific Department

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SINGAPORE'S TRADE ELASTICITIES: A DISAGGREGATED LOOK INTO THE ROLE OF GLOBAL VALUE CHAINS AND COMPLEXITY[1]

A. Introduction

Singapore is one of the world's most open economies, with the size of its trade (exports plus imports) reaching about 350 percent of its GDP. This reflects Singapore's role as a trading port and an oil and gas hub, but also the penetration of regional supply chains which has led to an increase in trade in intermediate goods. In this paper, we revisit the size and determinants of Singapore's trade elasticities, which are important in understanding the role of the exchange rate, competitiveness and external demand in the determination of output and trade balance. Trade elasticities are also critical to understand the transmission of monetary policy, in light of the use by the Monetary Authority of Singapore (MAS) of the nominal effective exchange rate as the monetary policy instrument.

The novelty of our empirical approach is that we explore the size of Singapore's trade elasticities at the disaggregated industry/product level. This allows us to consider the heterogeneity across different products in terms of their complexity and position in global value chains. Product and industry level heterogeneity are important in the context of the ongoing structural change in Singapore's economy and the tilt of exports towards more sophisticated products, which could allow Singaporean firms to capture a higher share of the value added.

Recent work in trade theory and empirics has focused on the role of global value chains (GVCs) and the distinction between gross versus value-added (net of imported inputs) trade data in estimating trade elasticities. For instance, in a partial equilibrium simulation Riad et. al. (2012) find that a downstream position in GVCs, or a higher share of imported foreign inputs in exports, cushions the impact of relative price changes on exports and imports. This is due to the foreign content in a downstream country's exports, which mitigates the impact of exchange rate changes, given that an appreciation lowers exports but it also implies cheaper imports. IMF (2015) empirically assesses the effect of real effective exchange rate changes on exports and imports distinguishing between GVC and non-GVC-related trade. They find that participation in GVCs and a country's position in GVCs (upstream versus downstream position) play an important role in trade elasticities. In particular, "upstreamness" is found to be associated with higher export price elasticities.

This study provides additional evidence, using Singapore and the heterogeneity of its traded products as a case study, on how integration in global value chains affects trade elasticities. Consistent with IMF (2015), we find that at the product level, more upstream products with a higher

[1] Prepared by Elif C. Arbatli and Gee Hee Hong with excellent research assistance from Jingzhou Meng.

domestic value-added share tend to be more price elastic. As highlighted in IMF (2015), this could reflect the dampened impact of exchange rate adjustments on downstream exports due to their high import content. However, the impact of domestic or foreign price changes on export elasticities could be different and would likely reflect the structure of the supply chain and the type of product. Consistent with theory, we find that an increase in the relative price of imports reduces import volumes. We also introduce interactive terms in the regressions to study the behavior of GVC-related imports. We find that the extent to which a product is used as input in exports has a magnifying effect on the price elasticity. This means that an increase in the relative price of imports leads to a larger decline in import volumes if the product is used as input in producing export products. This is counter-intuitive if the relative price change comes about through changes in exchange rates. Exchange rate depreciation makes imports more expensive but would also provide a boost to exports, pushing up demand for export-related imports. If the increase in relative import prices reflects changes in the foreign currency price of imported products, the import price elasticity would depend on the export price elasticity of the products that are being produced. Our results seem to be more consistent with the latter and the fact that we use highly disaggregated product-level data.

We also explore whether the complexity of a product has an effect on price and on demand elasticities. We find that economic complexity is related to export price elasticities: higher economic complexity is associated with lower price elasticity of exports. This relationship is stronger within certain product segments such as the machinery, mechanical appliances and computers as well as the pharmaceuticals segments.[2] The next section of this paper provides an overview of the structure and composition of Singapore's external trade. The consequent sections discuss the empirical strategy for estimating trade elasticities and results.

B. Structure and Role of Singapore's External Trade

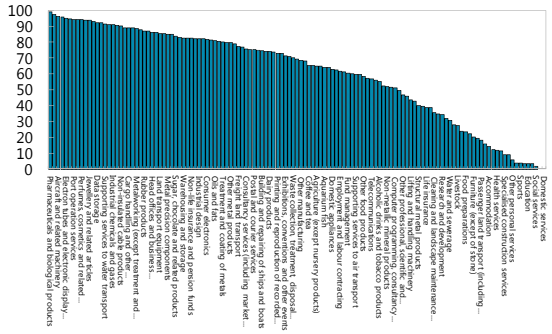
External Trade and Economic Structure. Singapore is a highly export oriented economy. Although net exports have declined from 26 percent of GDP before the global financial crisis to 19.1 percent of GDP in 2014, they are still one of the highest in the world. The export orientation of Singapore's economy can also be seen at the industry level. For instance, about 70 percent of all industries which produce 67 percent of Singapore's total output are export-oriented (Figure 1).[3] Singapore's output and exports are also highly dependent on imports. Most industries have a significant import input share, with the most import-intensive sector being the petroleum products industry (Figure 2). There is also a clear relationship between export orientation and import intensity at the industry level that becomes more significant for industries with an export share of output more than fifty percent

[2] Other studies have looked at the role of supply constraints in affecting trade elasticities. See Tulin and Raissi (2015) and Anand et al. (2015) for an application to India and South Africa respectively.

[3] Industries are classified as export-oriented when exports constituted more than 50 percent of final output. The calculations are based on Singapore's 2010 Input-Output Tables.

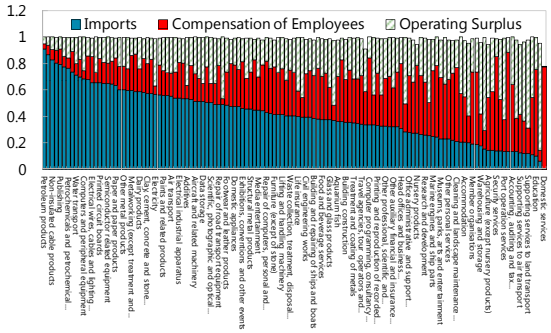
(Figure 3). Looking at the relationship between export orientation and the share of labor compensation in value added, there also seems to be a negative relationship, with more export–oriented sectors having a lower labor share in value-added (Figure 4).

Figure 1. Exports as Percent of Total Output by Industry
(percent)



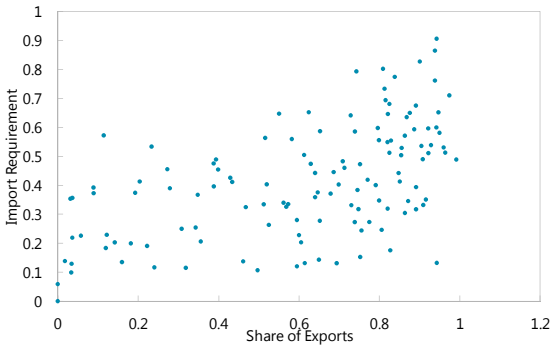
Sources: SingStat, Singapore 2010 Input-Output Tables

Figure 2- Share of Value-added by Primary Inputs
(share)



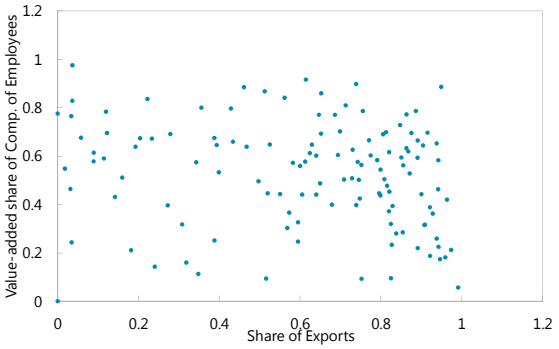
Sources: SingStat, Singapore 2010 Input-Output Tables

Figure 3. Import Intensity and Export Orientation of Sectors
(share)



Sources: SingStat, Singapore 2010 Input-Output Tables

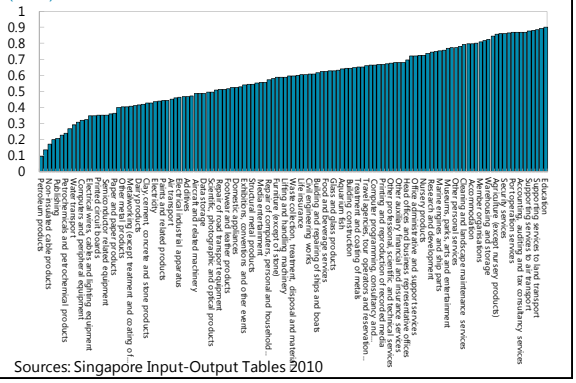
Figure 4. Share of Employee Compensation and Export Orientation
(share)



Sources: SingStat, Singapore 2010 Input-Output Tables

Most export industries in Singapore have a relatively low value-added share of exports (i.e. large import content), but there is some heterogeneity across sectors (Figure 5). Unsurprisingly, petroleum products sector stands out in terms of its low value-added content, reflecting the high value of imported crude oil relative to the refining and processing that takes place in Singapore. Sectors with relatively high value added are mainly services sectors, which is also intuitive. However, there are some service sectors such as water transport that have a low value-added share, reflecting the reliance of the sector on imported petroleum products as input. Singapore's exports of computers and electrical products also have relatively

Figure 5. Value-added Share of Exports for Different Industries
(share)

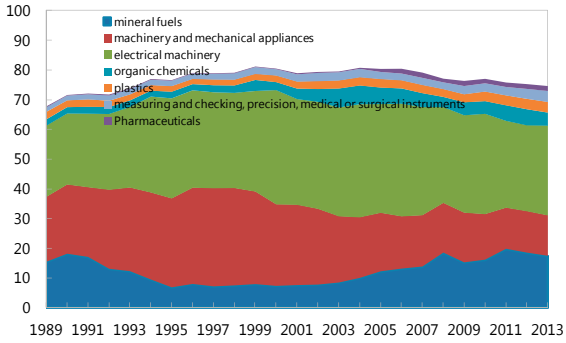


Sources: Singapore Input-Output Tables 2010

low value-added shares, reflecting Singapore's upstream position in global value chains.

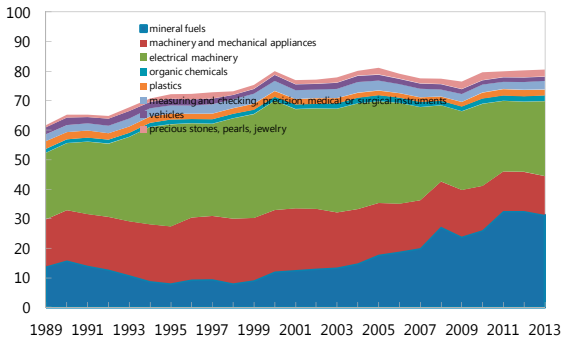
Composition of Trade. Singapore's exports have been dominated by the machinery and mechanical appliances, electrical machinery and equipment and mineral fuels and oils sectors (Figure 6). Over time, the share of organic chemicals, pharmaceuticals, plastics and measuring and checking, precision, medical or surgical instruments sectors have also increased.

Figure 6. Composition of Singapore's Gross Goods Exports by Major Product Groups
(percent)



Sources: UN Comtrade Database and IMF staff calculations.

Figure 7. Composition of Singapore's Gross Goods Imports by Major Product Groups
(percent)

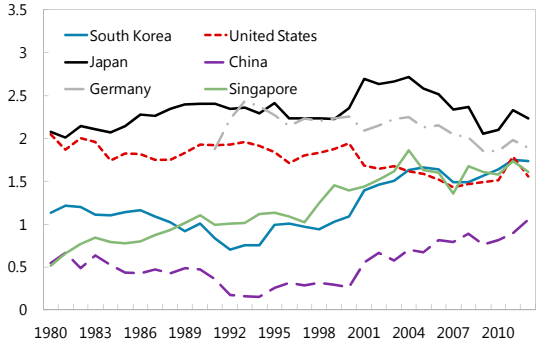


Sources: UN Comtrade Database and IMF staff calculations.

Important changes have taken place over time in the share of individual products under machinery and mechanical appliances and electrical machinery. For instance the share of computers in Singapore's gross goods exports declined from 14.1 percent in 2000 to 2.4 percent in 2013. Integrated circuits gained significant share in the 1990s, when they reached about 20 percent of total goods exports, and have remained an important export product since then. On the other hand, the export shares of radio receivers, monitors and projectors and related parts have declined since the 1990s. The composition of imports closely follows that of exports (Figure 7). Singapore's input-output tables confirm that a large share of imports is intermediate goods mainly imported by export-oriented sectors.

Economic Complexity. The notion of complexity of goods and services, originally described in Hidalgo and Hausmann (2009), is helpful in capturing the diversity and sophistication of a country's exports. Product complexity is captured by the fewness of the number of countries that export the product and the diversity of those countries' exports. If a product is produced by a small number of countries and if those countries have a diverse export product mix, the economic complexity of the product is measured to be higher. Economic complexity of Singapore is among the highest in the world and has increased steadily up until the mid-2000s, but has remained relatively flat since

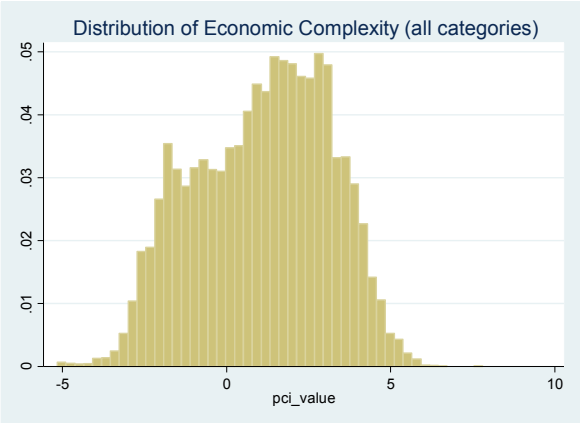
Figure 8. Index of Economic Complexity—Selected Countries
(level)



Sources: Hausmann et. al (2011) *The Atlas of Economic Complexity*. Puritan Press. Cambridge MA.

then (Figure 8). Although Singapore's export products have a high level of average complexity, there is significant variation across its export products (Figure 9).

Figure 9. Distribution of Economic Complexity by Export Products



C. Trade Elasticities

We estimate trade elasticities for import and export volumes using data from the UN Comtrade Database for about 1180 individual products for the 1989–2013 period. We estimate the following specifications for export and import volumes respectively using the Mean Group estimator of Pesaran and Smith (1995), allowing for product-specific fixed effects and price and demand elasticities.

$$\exp_{i,t} = c_{1,i} + \beta_i rp_{i,t} + \gamma_i y_{i,t}^{TP} + e_{i,t}$$

$$imp_{i,t} = c_{2,i} + \theta_i rp_{i,t} + \rho_i y_{i,t}^{SGP} + e_{i,t}$$

Where $\exp_{i,t}$ and $imp_{i,t}$ are the export and import volumes for individual products at the level of 6-digit HS codes. The relative price variable for the export volume regression is calculated as Singapore's export price divided by the average global import price of the same product that year. Each 6-digit price is calculated by dividing the total trade value (in USD) by total quantity. We obtain the global import price using data on the value and volume of total world imports of the product aggregating across all countries' imports.[4] The relative price for Singapore's imports is calculated

[4] In other studies, the relative export price or the real effective exchange rate for individual product groups is estimated by using domestic export price multiplied by the nominal effective exchange rate and divided by the domestic price of the product in trading partners. The ability to match sector specific prices across trading partners has proven to be complicated, depending on the product group and data availability. This measure of relative price has the advantage of being product-specific at a much detailed level of disaggregation and capture Singapore's export price relative to its competitors.

using Singapore's import price[5] divided by Singapore's Supplier's Product Index. Foreign demand ($y_{i,t}^{TP}$) is calculated as a weighted average of demand by Singapore's trading partners, whereby the weights are based on the share of Singapore's exports to different trading partners at the HS 2-digit product group level. Trading partners' demand is estimated by total imports of the country in U.S. dollars, divided by the U.S. GDP Deflator. Domestic demand ($y_{i,t}^{SGP}$) is captured by Singapore's real GDP. All variables enter in log form.

In the second stage of our analysis, we explore how different product or industry characteristics affect trade elasticities. We explore two factors: 1) economic complexity; 2) value-added in exports and the global supply chains. The economic complexity index is available for individual products at the HS 4-digit level for 1995–2012. We use this data to match Singapore's export and import products with economic complexity.[6] To explore the role of domestic value added we link information on the domestic value content of Singapore's exports from different sectors from the input-output tables to different export products.[7] This allows us to have a product-specific measure of the domestic value-added content. We construct a similar measure for imports, which captures the extent to which imports into Singapore are used as inputs in exports. We construct this index by using information from input-output tables. In particular, we use information on the composition of sectors that import a certain product and the direct import content of different sectors' exports.[8]

D. Results

Baseline results and heterogeneity in trade elasticities. Table 1 presents estimates of export elasticities for Singapore. The average relative price and demand elasticities of Singapore's exports are estimated at -0.24 and 0.68 respectively, showing that export volumes are affected by changes in both relative prices and foreign demand. The estimates at the broad product groups show that there is significant variation (Figure 10). The price elasticity varies between 0 and -0.8, while the demand elasticity varies between 0 and 2.5.The distribution of both elasticities is in line with what we would expect. Categories at HS 2-digit level that exhibit low price elasticity (in absolute terms) are the categories that involve sophisticated technology (for instance, man-made staple fibre, vegetable fibre and arms and ammunition). On the other hand, categories that exhibit high price elasticity are

[5] Import price is calculated by dividing the total import value (in USD) by total import quantity, converted into Singapore dollars.

[6] As mentioned earlier, the complexity index for individual products is available at the HS 4-digit level for 1995–2012, which allows us to match Singapore's export products with the index of complexity. We assume that all 6-digit products under the same 4-digit product code have the same complexity. For years that we do not have the product-level economic complexity index we assume that it is the same as the closest available year.

[7] We match industries in Singapore's input-output tables with the HS 4-digit level product codes that is provided as part of the input-output tables. When there is a match between a certain product code and multiple input-output industry codes, we use a weighted average of the input-output industries with the exports of that industry used as weights.

[8] One caveat in this index is the fact that we only use the 2010 Input-Output Tables and therefore do not account for potential changes over time in the extent to which a certain product is used in exports.

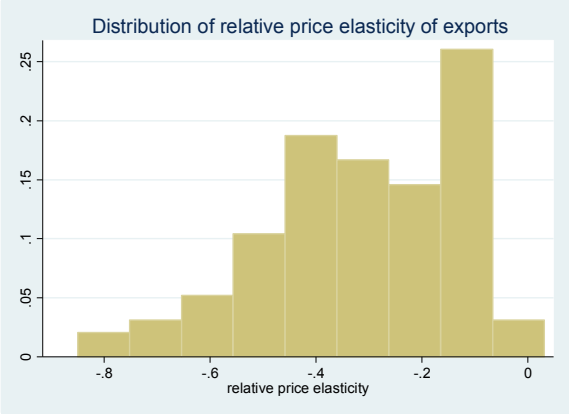
more labor-intensive, commodity products such as furniture, beddings, mattresses and live animals. Food related items were among the top 3 categories that show the highest demand elasticity such as miscellaneous edible preparations, beverages and preparation for meat. Some examples of the categories that exhibited low income elasticities are commodity goods, such as cork and woods.

Table 1. Export Elasticities

	All Sectors	Machinery, computers	Electrical machinery Telecommunications equip.
VARIABLES	log(export volume)	log(export volume)	log(export volume)
log_relativeprice	-0.237***	-0.487***	-0.477***
	(0.00406)	(0.00406)	(0.00917)
log_foreign_demand	0.680***	0.323***	0.764***
	(0.00988)	(0.0160)	(0.0243)
Constant	1.615***	4.104***	-2.267***
	(0.214)	(0.368)	(0.550)
Observations	93,494	9,888	4,395
R-squared	0.408	0.847	0.898

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 10. Distribution of Export Elasticities



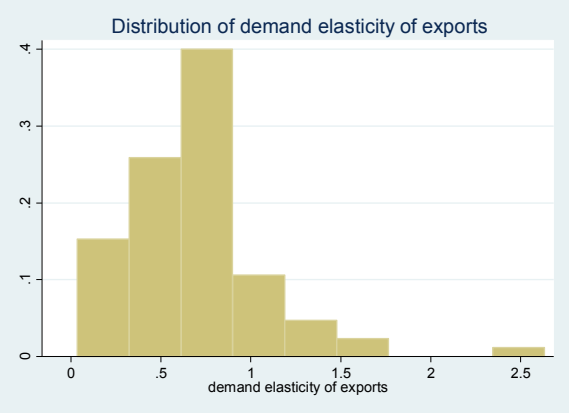
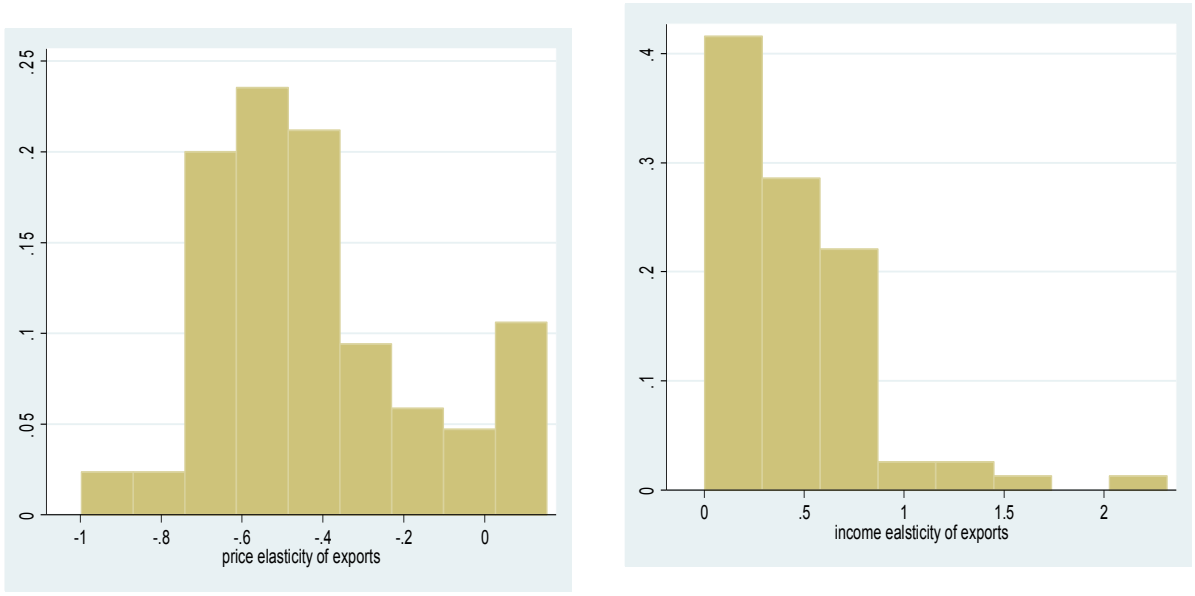


Table 1 also shows the estimates for two important export product groups for Singapore: HS 2-digit product category 84, related to machinery, mechanical appliances and computers and HS 2-digit category 85, related to electrical machinery, equipments and telecommunications equipments. Both sectors have similarly higher price elasticity than the average reported in Table 1, but the demand elasticity of electrical machinery sector is higher.

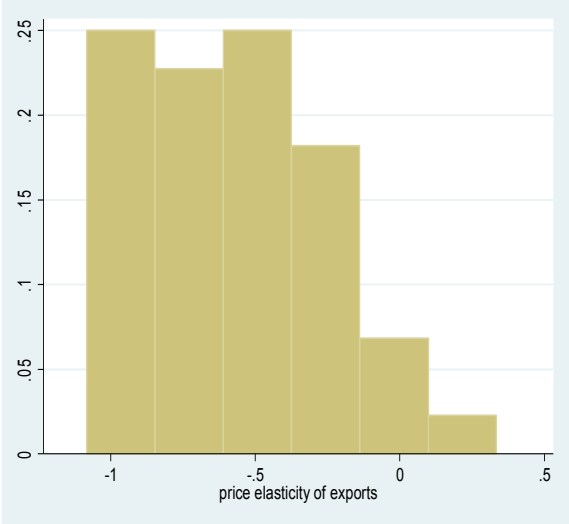
Within these two sectors, the variance of trade elasticities is also quite substantial. This is relevant given the importance of these two sectors in Singapore's exports and the fact that broad product group averages can hide important product-level heterogeneity. The following charts show within category 84, the variation of price and income elasticities of 4-digit sub-sectors (Figure 11). The most important 4-digit subsector of category 84 is computers (HS category 8471), which constituted 2.4 percent of Singapore's total goods exports in 2013 (only third to refined petroleum and integrated circuits). This category shows a low price elasticity of -0.05 and a large income elasticity of 0.7.

Figure 11. Distribution of Price and Income Elasticities within Category HS 84



The following two charts reveal the variation of export elasticities for electrical machinery, equipments and telecommunication equipments sector (Figure 12). Integrated circuits (category 8542), which has accounted for 20 percent of the SGP's total goods exports in 2013; show an income elasticity of 0.89 and a price elasticity of -0.49.

Figure 12. Distribution of Price and Income Elasticities within Category HS 85



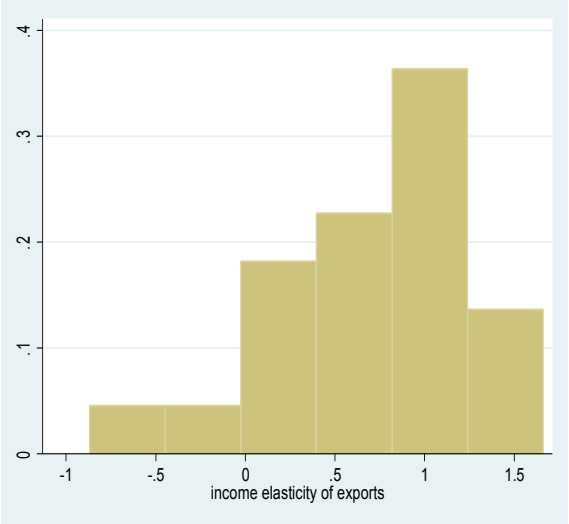


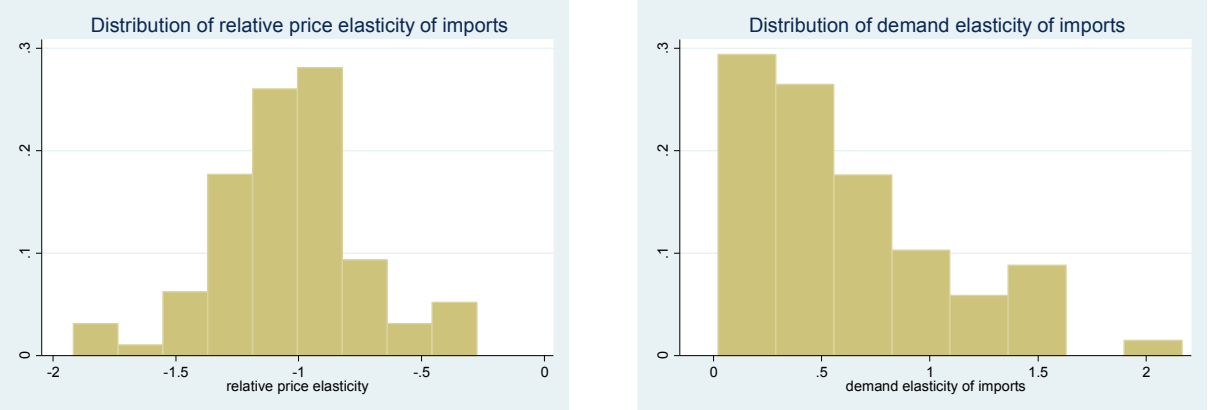
Table 2 presents estimates of import elasticities with respect to relative price and income. The average relative price elasticity of Singapore's imports is -1.1 and the average income elasticity is 0.32, but there is significant variation across product groups (Figure 13). The categories that exhibit low elasticity of volumes to relative prices are heavy-manufacturing, particularly those related to transportation such as ships, aircraft and railway or tramway locomotives. As in the case of export price elasticity, the categories that are most sensitive to relative price changes are food-related categories, such as sugar, preparations of cereals, flour, starch or milk, and preparation of meat. On income elasticity, the categories that exhibit high elasticity to changes in demand are some consumption goods such as perfumes and pharmaceutical products, while some categories are less sensitive to changes in demand, like electrical machinery and base metal

Table 2. Import Elasticities

VARIABLES	log(import volume)
log_relativeprice	-1.107***
	(0.00390)
log_demand	0.317***
	(0.0165)
Constant	6.339***
	(0.200)
Observations	104,460
R-squared	0.617

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0

Figure 13. Distribution of Import Elasticities



Explaining Trade Elasticities. In this section we explore the relationship between trade elasticities and product/industry characteristics. First, given the importance of industries with high economic complexity in SGP's trade, we first assess the relationship between economic complexity and trade elasticities. Second, we focus on another prominent feature of SGP's trade, the high share of import content in Singapore's exports. Specifically, using input-output tables, we see if the degree of import intensity in exports and GVC-related vs. non-GVC related imports can also help us understand the heterogeneity in trade elasticities.

Table 3 below shows estimates of baseline regressions for export and import volumes, where we interact relative price and demand with the economic complexity index. The estimated coefficients are small, showing a limited impact of economic complexity on trade elasticities for both exports and imports. When we look at how complexity is related to trade elasticities within individual product groups, we find a significant and large effect on price elasticities. It is important to look at the sensitivity of trade elasticities within individual groups because Singapore's trade is concentrated in a few major product groups and there is significant product heterogeneity within those product segments (Figure 14). For instance within the machinery, mechanical appliances and computers as well as the pharmaceuticals groups, price elasticity declines with the complexity of the product, consistent with our priors (Table 4). This relationship is somewhat smaller for the electrical machinery, equipments, telecommunications equipments and the organic chemicals segments. The relationship between complexity and demand elasticities is pretty small within individual product groups.

Table 3. Effect of Economic Complexity on Trade Elasticities

VARIABLES	log (export volume)	log (import volume)
log_relativeprice	-0.204***	-1.151***
	(0.00692)	(0.00567)
log_foreign_demand	0.193***	0.287***
	(0.0207)	(0.0290)
relativeprice*complexity	-0.00811***	0.0282***
	(0.00246)	(0.00180)
foreigndemand*complexity	-0.00786***	0.00712***
	(0.000914)	(0.000603)
Constant	12.61***	6.601***
	(0.451)	(0.358)
Observations	67,059	75,963
R-squared	0.403	0.620

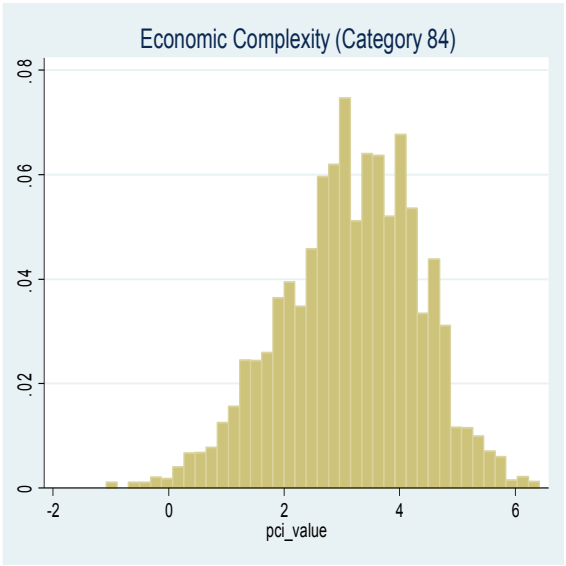
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Effect of Economic Complexity on Trade Elasticities for Major Product Groups

	Machinery, computers	Electrical machinery Telecomm. equip.	Organic chemicals	Pharmaceuticals
VARIABLES	log(export volume)	log(export volume)	log(export volume)	log(export volume)
log_relativeprice	-0.513***	-0.510***	-0.187***	-0.656***
	(0.0122)	(0.0196)	(0.0167)	(0.165)
log_foreign_demand	-0.933***	0.169***	0.639***	0.0996*
	(0.136)	(0.0595)	(0.0195)	(0.0573)
relativeprice*economic complexity	0.00781**	0.0176**	0.0235***	0.135**
	(0.00353)	(0.00718)	(0.00556)	(0.0541)
foreign_demand*economic complexity	0.00406**	0.00638**	0.00503***	0.0420**
	(0.00171)	(0.00280)	(0.00187)	(0.0171)
Constant	32.14***	10.87***	2.983***	10.46***
	(3.059)	(1.332)	(0.420)	(0.840)
Observations	7,269	3,195	4,502	226
R-squared	0.874	0.918	0.974	0.942

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 14. Distribution of Complexity Index within Individual Product Groups



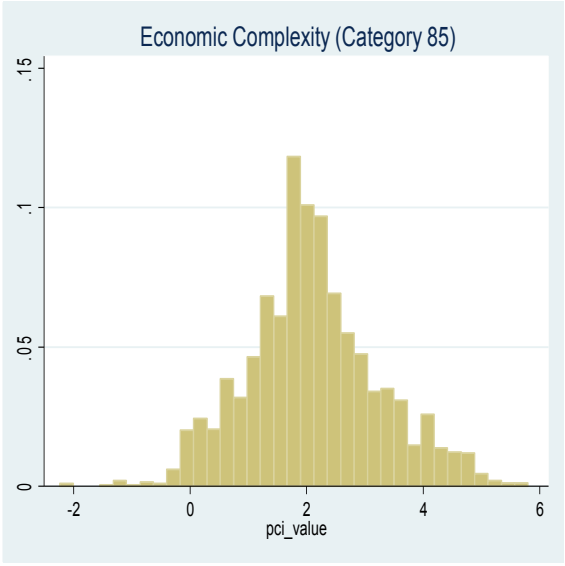
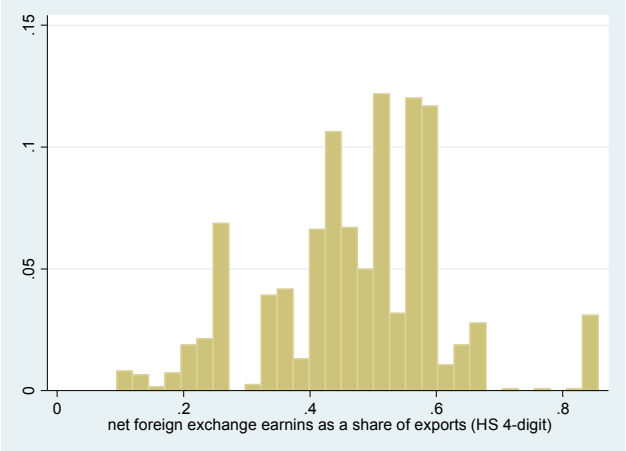


Figure 15. Distribution of Domestic Value-added Share of Exports by Product



We next consider the impact of value-added in exports and the end-use of imported products on trade elasticities. As discussed earlier, Singapore's exports typically have high import content. However, there exists substantial heterogeneity in the import intensity, as shown in Figure 15 (at HS 4-digit level), which shows the share of domestic value-added in exports. The higher domestic valued-added or lower import content an exported product has, one can conjecture a higher sensitivity of export volume to changes in relative price.

The regression results reported in Table 5 uses the domestic value-added share of different products, which we obtain by matching products with industry characteristics in Singapore's input-

output tables, as an interaction variable. Consistent with our expectations, the higher is the domestic value-added share of exports, the higher is the absolute value of the price elasticity of exports. The impact of domestic value added share on demand elasticity is negative, indicating that products with higher domestic value added also demonstrate lower demand elasticity.

Table 5. Effect of Domestic Value-added Share on Export Elasticities

VARIABLES	log (export volume)
log_relativeprice	-0.179***
	(0.0249)
log_foreign_demand	0.262***
	(0.0221)
Relativeprice*domestic value added	-0.0841*
	(0.0472)
foreigndemand*domestic value added	-0.122***
	(0.0170)
Constant	12.14***
	(0.450)
Observations	67,059
R-squared	0.404

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6. GVC-Related Imports and Import Elasticities

VARIABLES	log(import volume)
log_relativeprice	-1.001***
	(0.00718)
log_demand	0.288***
	(0.0167)
relativeprice*import leakage	-0.332***
	(0.0190)
demand*import leakage	0.0655***
	(0.00790)
Constant	6.431***
	(0.201)
Observations	103,507
R-squared	0.621

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Finally, we consider the use of imports, for instance the extent to which imports are used as inputs in exports, to explain differences across products in terms of their import elasticities. Singapore's high import content of exports implies that an important share of imports is used in producing exported goods. By linking information on different industries from input-output tables with imported products, we construct a measure of the share of the imported product that is leaked outside of Singapore through exports and the share that goes to final consumption and capital. Our results show that the price elasticity of imports is higher for products that are more intensively used as inputs in producing exports, or leaked out of Singapore (Table 6). If relative prices adjust due to a change in the exchange rate, this would lower the relative price of exports depending on the domestic value-added content, increase demand for exports depending on the size of the price elasticity, and therefore lead to an increase in demand for imports. In this scenario, the increase in the relative price of imports can lead to the perverse effect of increasing demand for imports. If the relative price change is due to an increase in the foreign currency price of the imported product, then the export price would increase, leading to a decline in both export and import volumes. Our results seem to suggest that relative price adjustments in this exercise mainly reflect changes in relative prices as opposed to exchange rates, which would be consistent with the fact that we use highly disaggregated product-level data. Finally, consistent with our priors, capital goods have lower price and demand elasticity (Table 7).

Table 7. Capital and Consumption Goods and Import Elasticities

VARIABLES	log (import volume)	log (import volume)
log_relativeprice	-1.245***	-1.116***
	(0.00530)	(0.00444)
log_demand	0.375***	0.318***
	(0.0165)	(0.0166)
relativeprice*capital goods	0.962***	
	(0.0240)	
demand*capital goods	-0.169***	
	(0.0143)	
relativeprice*consumption goods		0.0880***
		(0.0180)
demand*consumption goods		-0.0686***
		(0.00771)
Constant	5.447***	6.503***
	(0.201)	(0.201)
Observations	103,507	103,507
R-squared	0.625	0.619

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

E. Conclusions

External trade plays a very important role in Singapore's economy, providing an important share of total value added. Singapore's exports have a relatively large import share, but they also have a high level of complexity. As emphasized in previous studies, value-added in exports plays an important role in trade elasticities. We find evidence that this is indeed the case for Singapore's export products. Products that have higher domestic value-added share also tend to have higher export price elasticity. Economic complexity is also related to export price elasticities: higher economic complexity is associated with lower price elasticity of exports. This relationship is stronger within certain product segments such as the machinery, mechanical appliances and computers as well as the pharmaceuticals segments. Trade elasticities are important to understand Singapore's exchange rate based monetary policy transmission. Exchange rate changes can affect profits and trade volumes differently, depending upon the price pass-through to import and export prices and the price elasticity of exports and imports. The import and export price pass-through can in return depend on trade elasticities. We find that there is important product heterogeneity with respect to trade elasticities; both across different product groups but also within individual product groups. This implies that structural changes in the product composition of trade can lead to sizeable changes in Singapore's trade elasticities.

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