An Analysis of export competitiveness of clean energy-related products

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Clean energy-related products are indispensable for the transition to clean energy and are also expected to be one of the new growth industries in terms of industrial policy. In this study, silicon transistors, photoelectric conversion elements, lithium-ion batteries and electric vehicles are taken as clean energy-related products, and the current status of export competitiveness and resistance to price competition are analyzed. Armington elasticity was estimated for each product category, and it was confirmed that the smaller the Armington elasticity, the less likely the product is to be exposed to price competition. Using the Armington elasticity, a sensitivity analysis was also conducted on the impact of higher domestic electricity prices on the competitiveness of exports of products from Japan via domestic output prices. For products that are more likely to be exposed to price competition, we confirmed that higher domestic energy prices lead to a certain degree of export decline. This suggests that stable domestic energy prices contribute to the transition to clean energy and the growth of related industries.

Keywords : Clean energy-related products, Armington Elasticity, Export Competitiveness, Energy Price

1. Introduction

The importance of expanded adoption of renewable energy and progress in electrification have been highlighted as measures to achieve the goals of the Paris Agreement. These measures would be supported by such clean energy products as solar photovoltaic panels, storage batteries, power semiconductors, and electric vehicles. The Green Growth Strategy prepared in 2021 notes expectations for growth in clean energy related industry from the standpoint of industrial policy. This research focuses on the import and export competitiveness of clean energy related products in Japan that are becoming increasingly important from the standpoint of both the transition to clean energy and securing industrial competitiveness. We also analyzed the impact of the rising electricity prices that remain a concern moving forward as the international energy situation changes drastically.

2. Export competitiveness for clean energy products

2.1 Clean energy-related products analyzed in this paper

Table 1 lists the clean energy-related products analyzed for this paper and their HS codes. For this paper, we looked at silicon transistors, represented by the common power semiconductor that supports electrification technology, photoelectric conversion devices which are semiconductors used for solar photovoltaic power generation, lithium-ion batteries installed in stationary storages or onboard electric vehicles, and various electric vehicles such as hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), and battery electric vehicles (BEV). We covered products dating from the year 2012 and later, the year after the Great East Japan Earthquake.

Table 1. Clean energy products analyzed for this paper

Item	HS code (Export/Import)
Silicon transistor	854129910 / 854129010
Photoelectric Conversion Device	854140990 / 854140090
Lithium-ion battery	850760000 / 850760000
Electric Vehicl (HEV)	870340900 / 870340000
Electric Vehicle(PHEV)	870360900 / 870360000
Electric Vehicle(BEV)	870380900 / 870380000

Source: Trade Statistics, Ministry of Finance [1] "Export Statistics Item Tables" and "Import Statistics Item Tables"

2.2 Trade Specialization Index

We first calculated the changes in the Trade Specialization Index (TSI) in the following manner as an indicator of the export competitiveness of each product.

Trade Specialization Index = (Export amount - Import amount)/(Export amount + Import amount)

By definition, the TSI ranges from -1 to 1. When the TSI is

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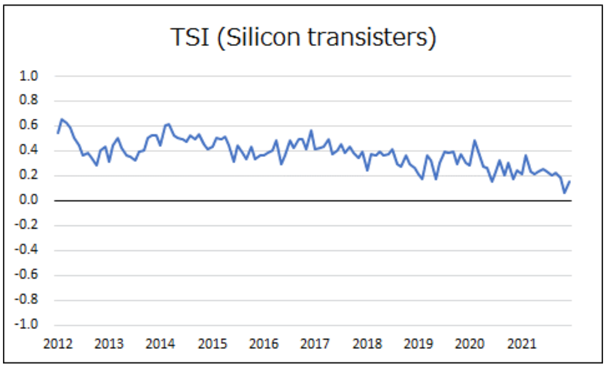
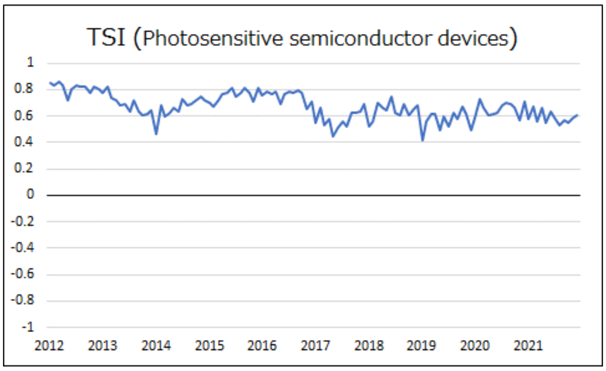
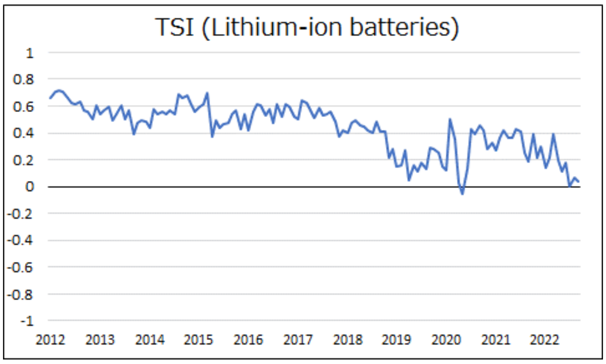


Source: based on Trade Statistics, Ministry of Finance [1].



Source: from reference [2].



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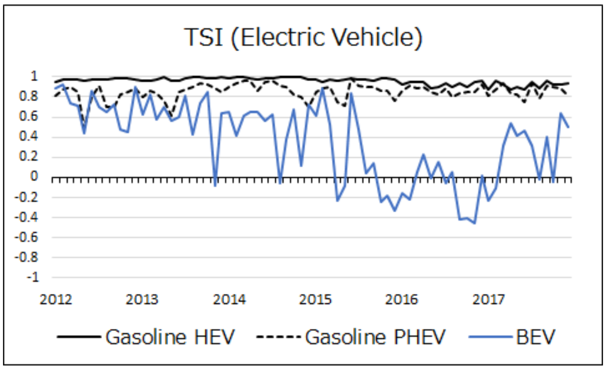


Source: based on Trade Statistics, Ministry of Finance [1].

Figure 1: Trade Specialization Index for Clean Energy Products

close to 1, it is considered export specialized, or in other words, it denotes that the product has high export competitiveness. On the other hand, when the number is close to -1, it denotes that the product is import specialized, or that it has low export competitiveness. Horizontal trade, a state common in much of the trade of goods where products in the same category are simultaneously imported and exported, has been observed, in which case the TSI becomes close to 0. This tendency is notable for goods with a high level of product differentiation.

Figure 1 shows the monthly changes of the TSI for the clean energy products listed in Table 1. The TSI for silicon transistors, a primary component for power semiconductors, has been gradually trending downward, and broke 0.2 at the end of 2021. The TSI for photosensitive semiconductor devices, a primary component in solar photovoltaic panels, also declined slightly from 0.8 in 2012 to 0.6 in 2021. Furthermore, a downward trend is continuing for the TSI of lithium-ion batteries, and has been approaching zero since the summer of 2022. Finally, a look at the three types of electric vehicles (hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), and battery electric vehicles (BEV)), shows that the TSI for HEVs has remained stable as export specialized at around 0.8 to 0.9, despite a slight decline from 2020. In comparison, the TSI for BEVs is beginning to trend towards import specialized with months in the negative increasing in frequency since 2020 despite major fluctuation in part due to inadequate domestic demand.

However as noted before, when the TSI approaches zero, it means that the level of horizontal specialization is high in the relevant product category, and this cannot be directly connected to a decline in export competitiveness.

3. Elasticity of substitution between domestic and imported goods

One factor behind increased horizontal specialization in the same product category is product differentiation. According to Armington[3] , when domestic goods and imported goods are not homogeneous, but rather are related as differentiated imperfect substitutes, then horizontal specialization will occur with the simultaneous import and export of the same product.

Here we consider a model of two countries: country A and country B. The goods produced in each country are differentiated. The total demand for the goods from country A XA are the total of the domestic demands for countries A XA_A and B XA_B, while the total demand for the goods from country B XB are also the total of the domestic demands for countries A XB_A and B XB_B. In this case, the substitution elasticity between the domestic goods and imported goods in country A (the Armington elasticity) is equivalent to β in Formula (1) below. Here P_A is the production price in country A, while P_B is the production price in country B.

$$XA_A = b_A(P_A/P_B)^{\beta} XB_A \quad (1)$$

Estimation of Armington elasticity according to its original definition requires data on domestic demand for each of the products in Table 1 equivalent to XA_A and XB_A. To avoid this, we estimate the following model using only trade data, based on the referenced literature [4].

For the sake of simplicity, assuming that the demand for each product in each country depends on the economic scale (such that the demand in country B is λ times country A), the export and import volume of country A are set as E_A and M_A respectively. Similarly, the export and import volume of country B are set as E_B, M_B respectively. Accordingly, E_A and M_A can be shown in the following manner.

$$E_A = M_B = XA_B = \lambda XA_A \quad (2)$$
$$M_A = E_B = XB_A \quad (3)$$

From equations (1)-(3), we obtain the following equation (4). Here, α is a constant.

$$E_A/M_A = \alpha(P_A/P_B)^{\beta} \quad (4)$$

Equation (5) is formulated as a state-space model by taking the logarithm of equation (4).

$$log(E_A/M_A) = \mu_t + \beta log(P_A/P_B) + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma_\varepsilon^2)$$
$$\mu_{t+1} = \mu_t + v_t + \xi_t, \quad \xi_t \sim N(0, \sigma_\xi^2)$$
$$v_{t+1} = v_t + \zeta_t, \quad \zeta_t \sim N(0, \sigma_\zeta^2) \quad (5)$$

Table 2 shows the estimation of the parameter β equivalent to the Armington elasticity when monthly dummy data is added to equation (5).

When the absolute value of β is small, then the impact on trade volume when the price of the imported good changes relative to the domestically produced good is small, and changes in factors other than the price may have led to increased product differentiation. However, when the absolute value of β is high, it means that the trade volume changes elastically when the relative price changes. Looking at Table 2, we see that the elasticity of lithium-ion batteries is particularly high at -4.6, and that it responds to relative price changes very sensitively. Conversely, the elasticity of hybrid and plug-in hybrid vehicles is low at -0.13 and -0.35 respectively, and these products are therefore less likely to be exposed to price competition compared

Table 2: Armington Elasticity of Clean Energy Related Products

Item	β(Armington elasticity)	t-value	R^2	Estimation Period
Silicon transistor	-0.8332	-7.13	0.489	2012.1-2021.12
Photoelectric Conversion Device	-0.7449	-10.59	0.694	2012.1-2021.12
Lithium-ion battery	-4.6074	-3.72	0.746	2020.1-2021.12
Electric Vehicl (HEV)	-0.13036	-0.612	0.561	2017.1-2021.12
Electric Vehicle(PHEV)	-0.35274	-0.875	0.280	2017.1-2021.12
Electric Vehicle(BEV)	-0.8336	-2.896	0.406	2017.1-2021.12

Notes: Estimation results for β in equation (5).

to BEVs, silicon transistors, and photosensitive semiconductor devices, or in other words that they are highly resistant to price competition. Note that according to reference [2], the Armington elasticity of photosensitive semiconductor devices and lithium-ion batteries was estimated, resulting in numbers of 0.702 from January 2012 to December 2021, and 1.663 from January 2012 to September 2022 respectively. Because they used data on export price rather than domestic output price, the results are different than Table 2.

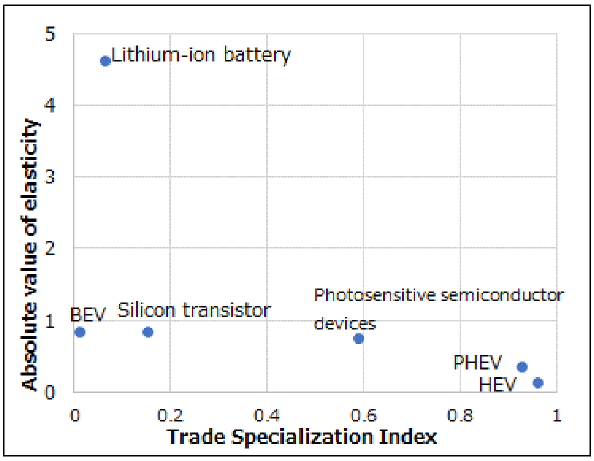
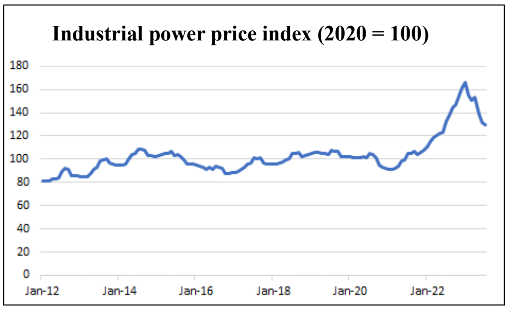


Figure 2: Armington Elasticity (absolute value) and the Trade Specialization Index

Figure 2 shows the distribution of the analyzed products with the horizontal axis representing the TSI for the last month of the analyzed period (December 2021) and the vertical axis representing the absolute value of the Armington elasticity. As we have shown, products with a TSI close to 1 and a low Armington elasticity (absolute value) have a high degree of product differentiation and high export competitiveness. We can see that of the products we analyzed, this applies to HEVs and PHEVs. In contrast, we can see that the TSI of lithium-ion batteries is close to 0 and that the Armington elasticity (absolute value) is high. Even ignoring lithium-ion batteries, we can see from Figure 2 that the lower the Armington elasticity, the higher the TSI. In other words, export specialized products tend to be less exposed to prices.

4. Sensitivity Analysis: Impact of Higher Electricity Rates

Figure 3 shows the changes in the industrial power price index according to the Corporate Goods Price Index from the Bank of Japan. Here we can see that the price of electricity temporarily doubled in 2020 compared to the price between 2007 and 2010, influenced by the increase in fuel prices following the invasion of Ukraine by Russia. Below, we estimate a model to regress the domestic output price of each product on the domestic industrial power price in order to carry out sensitivity analysis on the impact of higher domestic electricity prices on the export competitiveness of products from Japan via the domestic output price.



Source: compiled from Bank of Japan, "Corporate Goods Price Index" [5].

Figure 3: Industrial Power Price Index

Equation (6) below is a model that regresses the output price P_A of the clean energy-related products we analyzed for country A on the industrial power price index P_E. As in equation (5), it is formulated as a state-space model.

$$\begin{aligned} log(P_A) &= \mu_t + \gamma log(P_E) + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \\ \mu_{t+1} &= \mu_t + \nu_t + \xi_t, \quad \xi_t \sim N(0, \sigma_\xi^2) \\ \nu_{t+1} &= \nu_t + \zeta_t, \quad \zeta_t \sim N(0, \sigma_\zeta^2) \end{aligned} \quad (6)$$

Table 3 shows the estimation of parameter γ by adding monthly dummy data to equation (6). Because we could not obtain the separate data for hybrid vehicles, plug-in hybrid vehicles, and battery electric vehicles from the domestic output price data used in the analysis, we used the average output price for electric vehicles here. According to Table 3, the product for which the output price was influenced the most by the rise in electricity prices was silicon transistors, with a rise of 0.15% in output price per 1% rise in electricity prices. In comparison, the output price for electric vehicles (average) only rose 0.02% for each 1% rise

Table 3: Elasticity of Output Prices of Clean Energy Related Products to Electricity Prices

Item	γ(elasticity to electricity rates)	t-value	R^2	Estimation Period
Silicon transistor	0.1458	2.04	0.069	2012.1-2021.12
Photoelectric Conversion Device	0.083	2.38	0.157	2012.1-2021.12
Lithium-ion battery	0.0639	6.71	0.306	2020.1-2021.12
Electric Vehicl (average)	0.0242	1.92	0.71	2017.1-2021.12

Notes: Estimation for γ in equation (6)

in electricity prices.

Next, Table 4 shows the results when we double P_E for country A in equation (6) and make the output price P_B for country B unchanged, and look at the changes in export volume E_A via equations (5) and (6). Because we were using the same output price for electric vehicles, we used BEVs which had the largest Armington elasticity in Table 2 for this calculation.

Table 4: Sensitivity Analysis vs. Doubled Electricity Prices

Item	output price	export volume
Silicon transistor	up 10.6%	down 8.1%
Photoelectric Conversion Device	up 5.9%	down 4.2%
Lithium-ion battery	up 4.5%	down 18.5%
Electric Vehicl (average)	up 1.7%	down 1.4%

Table 4 shows that the product for which the output price is influenced the most is silicon transistors, but looking at the influence on export volume, lithium-ion batteries are influenced the most. This is because the Armington elasticity (absolute value) estimated in Table 2 was the highest for lithium-ion batteries. The next highest influence is silicon transistors, and the import volume decline is 18.5% and 8.1% respectively. Meanwhile, while the Armington elasticity of electric vehicles (BEVs) is almost the same as silicon transistors, the sensitivity of the domestic output price thereof to electricity prices is low, and therefore the impact on export volume is limited.

4. Conclusions

Clean energy related products are not only essential for the transition to clean energy, but expectations for the domain to become a growth industry from the standpoint of industry policy are rising. This paper considered several clean energy products and analyzed their current export competitiveness and resistance to price competition. We confirmed that for products that can easily be exposed to cost competition, a rise in domestic energy prices leads to a certain reduction in exports. Therefore, it can be said that stable domestic energy prices contribute to the transition to clean energy and related industry growth.

The rising prices of resources due to international instability are becoming a driving factor that accelerates the transition to clean energy primarily in Europe. However, because the energy density of renewable energy is generally low, a relatively large amount of resources are required to use it. As a result, the transition to clean energy can easily lead to demand pressure and rising prices on resources, including critical minerals and related materials. This analysis examines the impact of energy costs on production prices and imports and exports of clean energy-related products. The results indicate that the growth of clean energy-related industries requires that the costs of decarbonisation policies, including energy prices, and their impact on product exports be fully considered when formulating policies. This is crucial not only for achieving Japan's carbon neutrality targets, but also for its industrial strategy.

The results also suggest that when considering the export competitiveness of clean energy related products, it is important to prepare for price fluctuations not only in energy prices but with relation to the procurement of raw materials and related materials.

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