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Trade openness and output volatility for the Japanese manufacturing industry

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ABSTRACT

This study investigates the relationship between trade openness and output volatility in the Japanese manufacturing industry. It explores whether this relationship depends on the underlying economic environment and industry heterogeneity. The fixed-effect model was applied to the industry panel after estimating volatility using the residual approach. The main findings are as follows: First, openness decreased output volatility before the Plaza Accord in 1985 but increased it afterward. Second, openness decreased output volatility in lower technology sectors before 1985 and increased it thereafter. Third, openness increased output volatility in high-technology sectors before 1985 but did not affect volatility afterward. Fourth, both price and its volatility increased output volatility, while government taxes and subsidies decreased it. In conclusion, this study contributes to the understanding of the relationship between openness and volatility at the industry level by focusing on industry heterogeneity. It also provides insights into the impact of the Plaza Accord from a volatility perspective. The openness-volatility relationship depends on the economic environment and industry heterogeneity. The reversal of this relationship explains why Japanese manufacturers are less active in pursuing the global market after the Accord.

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Contribution/Originality: This study contributes to the existing research on the relationship between openness and volatility at the industry level by utilizing panel data from the Japanese manufacturing sector. It provides insights into industry heterogeneity underlying this relationship and enhances understanding of the impact of the Plaza Accord from a volatility perspective.

1. INTRODUCTION

Output volatility disrupts planning and investment, thereby altering the trajectory of industry development. An industry faces significant risk when it is open to international trade because of its exposure to external shocks and specialization. However, trade openness reduces output volatility by mitigating the impact of economic crises, as an industry becomes increasingly productive and resourceful when open. Therefore, investigating the relationship between volatility and trade openness is an open empirical question and is important for understanding industry growth.

This study investigates the factors affecting output volatility and its relationship with trade openness at the industry level by employing panel data from the Japanese manufacturing industry. The study examines whether the relationship between trade openness and output volatility at the industry level differs from that observed at the national level. It also explores whether this relationship depends on the underlying economic environment and industry heterogeneity in technology levels.

Although many studies have explored the relationship between openness and volatility at the national level, few have investigated it at the industrial level. Our study adds to existing industrial research by utilizing comprehensive industrial panel data compiled from the Japan Industrial Productivity (JIP) database. It provides insights into industry heterogeneity underlying this relationship, which cannot be captured in national-level studies. Therefore, our research can assist policymakers in developing industrial policies aimed at reducing output volatility.

There are extensive studies that have investigated the openness-volatility relationship at the country level (Avom, Kamguia, Ngameni, & Njangang, 2021a; Balavac & Pugh, 2016; Bejan, 2006; Calderón, Loayza, & Schmidt-Hebbel, 2005; Cavallo, 2006; Cavallo & Frankel, 2007; Duran & Fratesi, 2020; Easterly, Islam, & Stiglitz, 2001; Edwards, 2004; Giovanni & Levchenko, 2009; Guidotti, Sturzenegger, Villar, de Gregorio, & Goldfajn, 2004; Kose, Prasad, & Terrones, 2003; Lee, Ricci, & Rigobón, 2004; Martin & Rey, 2006; Mobarak, 2005; Ramey & Ramey, 1995; Rodrik, 1998; Sachs, 1985). Despite numerous studies, the impact of openness on volatility is not conclusive. Some studies argue that openness increases a country's exposure to external shocks that are not necessarily negatively correlated with internal shocks (Easterly et al., 2001; Kose et al., 2003; Rodrik, 1998). Other studies report that openness reduces volatility by moderating the impact of financial crises and diversifying external sources of shocks (Calderón et al., 2005; Calvo, Izquierdo, & Mejía, 2004; Calvo, Izquierdo, & Talvi, 2006; Cavallo & Frankel, 2007; Edwards, 2004; Guidotti et al., 2004; Martin & Rey, 2006; Sachs, 1985). Other studies suggest that the relationship depends on financial development and institutional quality (Avom et al., 2021a; Balavac & Pugh, 2016).

These studies have difficulty dealing with country-specific factors that affect the relationship between openness and volatility. Some studies average a variable over the entire period to measure volatility and obtain cross-sectional data, thereby excluding fixed country-specific factors (Bejan, 2006; Cavallo & Frankel, 2007). Other studies use a country panel to estimate the fixed effects model, failing to represent constant factors through within transformation (Avom et al., 2021a). These studies overlook the country-specific factors that intervene in the relationship.

For example, countries have different risk preferences underlying their relationships. Developing countries prefer growth over risk compared to developed countries, and output volatility is larger in the former than in the latter. Thus, volatility could be biased toward developing countries in country-level estimations. Preferences differ across countries and do not change easily. If this fixed factor is omitted, estimated results would be biased. An industry-level panel can address this problem because data are compiled from a single country, eliminating bias resulting from fixed country-specific factors.

A firm-level panel study can also address the issue because its data is compiled from a single country. Recent studies have explored the openness-volatility link by using firm-level data to leverage their extensive information to estimate the impact of openness resulting from intra-firm trade on employment volatility (Kim, 2022; Kiyota, Matsuura, & Higuchi, 2020). These studies show that firms engaged in intra-firm trade are affected differently by outside shocks compared with those engaged in inter-firm trade. These studies elucidate how outside shocks arising from firm trade are transmitted into employment shocks.

In firm-level studies, however, many small and medium enterprises (SMEs) represent the average relationship between openness and volatility in estimation due to their number. Thus, estimation fails to accurately represent the relationship of large corporate firms that might shape the industry. For example, a small number of large firms prevail in manufacturing industries including steel, shipbuilding, automobiles, and information technology (IT). For these industries, industry-level estimation can provide a better picture for policymakers to design industrial policies.

Furthermore, an industry generally faces greater risk when it is more open due to its exposure to external shocks. Output volatility disrupts planning and investment, altering the trajectory of industry development. Industries requiring fresh investments to sustain themselves are more affected by volatility than others. For example, the high-technology industry requires rapid investments that incorporate new technologies to remain at the forefront and is generally more trade-oriented to support its substantial investments. Does trade openness make the output of the high-technology industry more volatile than that of the low-technology industry? If not, what factors contribute to the stability of the industry despite increased exposure to external shocks?

In this regard, this study sheds some light on industry heterogeneity existing in the openness-volatility relationship for the Japanese manufacturing industry. This study will utilize rich panel data of the industry to account for fixed country-specific factors that confound the relationship, such as risk preferences. These factors include the legal, tax, political systems, and other institutions often ignored in country-level studies. Japan provides a very good case with its unique institutions that seldom change over the years.

Despite its significance, the openness-volatility nexus has not been fully investigated at the industrial level. We identified several previous studies in this regard (Giovanni & Levchenko, 2009; Imbs, 2007; Koren & Tenreyro, 2007). Giovanni and Levchenko (2009) show that openness increases output volatility at the industry level through increased specialization, but that openness reduces aggregate volatility by decreasing the correlation of an industry's volatility with other industries. Imbs (2007) reports that the growth and volatility relationship is positive in a sectoral estimation although it is negative in a cross-country estimation. This study suggests that industrial data isolate a component of aggregate volatility that is specific to each sector. Koren and Tenreyro (2007) decompose volatility into various sources and relate them to the stage of development. They show that the volatility of country-specific shocks decreases with development as the production structure becomes less volatile. All these studies suggest that the openness-volatility relationship can differ at the industry level from that observed at the country level.

Building on these studies, our research investigates the factors that determine volatility and the relationship between volatility and trade openness in the Japanese manufacturing industry. The study examines the impact of technology on volatility by classifying the total sample according to technology level. No other study addresses technological heterogeneity in this relationship.

Furthermore, our study explores how the 1985 Plaza Accord (PA), which significantly appreciated the Japanese yen, affected the relationship between openness and volatility. The PA marked a turning point in the Japanese economy, transforming it from a high-growth economy with a stable exchange rate into a low-growth economy with an unstable exchange rate. The study investigates how changes in the exchange regime influenced openness and volatility. It aims to contribute to understanding the impact of this historical multilateral trade agreement from a volatility perspective. This analysis may provide insights into the future trajectory of the global economy, especially considering the US-China conflict and ongoing tariff negotiations.

Our main empirical findings are as follows. First, openness decreased output volatility before the Plaza Accord in 1985, but it increased volatility afterward. Second, openness decreased output volatility for the lower technology sectors before 1985 and increased it thereafter. Third, openness increased output volatility for the high technology sectors before 1985, but it did not affect volatility afterward. Fourth, both price and its volatility increased output volatility, while government taxes and subsidies decreased it.

The remainder of this paper is organized as follows: Section 2 explains the methodology, data, and variables used in estimation. Section 3 presents empirical results on the relationship between openness and output volatility. Section 4 offers concluding remarks.

2. METHODOLOGY AND DATA

2.1. Methodology

To measure the volatility of a variable, the traditional approach uses the standard deviation of the growth rate over a certain period. This approach requires strong assumptions about the functional form of the long-term component. Therefore, we estimate output volatility by employing the residual approach proposed by Kurz and Senses

(2016). This approach is used widely in the volatility literature (as recent examples, (Avom, Kamguia, & Ngameni, 2021b; Chauvet et al., 2019; Kim, 2022; Kiyota et al., 2020)).[1]

To be specific, we derive volatility from the residuals of the conditional growth rate of output. First, the growth of output δ_{it} is estimated as the residual growth rate of output based on the following regression.

$$\delta_{it} = log(Q_{it}) - \log(Q_{it-1}) = \alpha_i + \gamma_t + \varepsilon_{it} \qquad (1)$$

where Q_{it} denotes output of industry *i* at time *t*. α_i is the industry fixed effects that capture the unobserved industry-specific characteristics, γ_t is the year fixed effects that capture year-specific shocks, and ε_{it} is the deviation of output from the industry average in year *t*. Then, output volatility σ is measured as the standard deviation of residual growth for a window of length *l*:

$$\sigma_{il} = \sqrt{\frac{1}{l-1}\sum_{t-l+1}^{t} \varepsilon_{it}{}^2} \qquad (2)$$

To investigate the relationship between output volatility and trade openness, we regress output volatility against trade openness along with a set of control variables. Our basic regression model is specified as follows:

$$\sigma_{ip} = \beta_1 + \beta_2 \log(Q_{ip}) + \beta_3 \log(Inv_{ip}) + \beta_4 \log(Emp_{ip}) + \beta_5 Open_{ip} + \beta_6 \log(Tot_{ip}) + \beta_7 \log(P_{ip}) + \alpha_i + v_{ip} \qquad (3)$$

where α_i the industry fixed effects, Inv_{il} denotes investment of industry *i* at period *p*, and Emp_{ip} is employment. $Open_{ip}$ is trade openness, Tot_{ip} is terms of trade, P_{ip} is output price, and v_{ip} is error terms. The explanatory variables are calculated as the average over a window of *l*.

Regarding control variables, investment embodies new technology that enables firms to produce better products, which makes them less subject to volatility. Thus, investment is expected to reduce volatility. Terms of trade decrease volatility despite increased openness (Avom et al., 2021b). Employment indicates the size of a firm, and large firms tend to have less volatility than small firms. This is because large firms can better manage their inventories, which reduces the impact of external shocks on volatility. Previous studies also show that output is more volatile in developing countries than in developed countries (Koren & Tenreyro, 2007). An increase in employment is expected to reduce volatility at the industry level as well.

The impact of output on volatility is not conclusive. Some studies find a negative relationship between volatility and growth, while other studies report a positive relationship (Ekinci, 2022). The impact of output prices on volatility depends on the firm's import and export structure (Malik & Temple, 2009).

To check the robustness of the basic model, we further add a set of control variables one by one in the estimation. The regression model now becomes:

$$\sigma_{ip} = \beta_1 + \beta_2 \log(Q_{ip}) + \beta_3 \log(Inv_{ip}) + \beta_4 \log(Emp_{ip}) + \beta_5 Open_{ip} + \beta_6 \log(Tot_{ip}) + \beta_7 \log(P_{ip}) + \beta_8 \log(Z_{ip}) + \alpha_i + v_{ip} \qquad (4)$$

where Z_{ip} represents additional control variables used to check the robustness of the basic model.

For this, we utilize government tax and subsidies as a proxy for industrial policy used to stabilize volatility. Fiscal and monetary policies increase output instability when they are poorly implemented (Fatás & Mihov, 2003; Hausmann & Gavin, 1996). However, government spending reduces output volatility in developed countries, but it does not affect volatility in developing countries (Bejan, 2006). While these studies analyze macroeconomic policies at the country level, we investigate microeconomic policies at the industry level.

Capital quality and IT (information technology) investment denote the flexibility of capital factors in detecting and adjusting to outside shocks. They help firms upgrade the quality of export products, thus reducing output volatility (Lapatinas, 2019). Labor quality represents human resources that industry can utilize to moderate the

[1]In another approach, volatility is proxied by the cyclical component of time-series after removing its trend components by using a statistical filter (Cariolle & Goujon, 2015). However, our approach is more systematic in estimating the residual component.

impact of shocks on volatility. Previous studies show that governance quality lowers output volatility (Balavac & Pugh, 2016). Similarly, the employment quality of industry is expected to reduce volatility.

Operating surplus proxies the financial resources that an industry can use to deal with volatility. Financial development helps a country to adjust to cyclical shocks, thus reducing output volatility (Hausmann & Gavin, 1996; Kim, 2007; Kose et al., 2003). Price volatility aims to control the impact of price shocks on output volatility, and the interaction between openness and price volatility is intended to manage their combined effect with openness. Price volatility is expected to increase output volatility.

2.2. Data and Variables

The data used in this study represent a balanced panel of Japanese manufacturing industries obtained from the 2015 Japan Industrial Productivity (JIP) Database.[2] Based on the database, we compiled a panel of 52 manufacturing industries for the period of 1970–2012. Later versions of the JIP Database include data from recent years, but data from periods earlier than 1994 are not available due to changes in industry classification. Therefore, this study uses the 2015 JIP database to ensure an adequate sample period representing the dynamics of the Japanese manufacturing industry since the 1970s.

In estimation, output is proxied by per capita value-added. Employment is represented by the number of workers, and investment and IT investment are given by the total investments in tangible fixed assets and IT assets, respectively. Indices of labor quality and those of capital quality are used for the quality of employment and investment, respectively.

Openness is proxied by the share of exports and imports in the output. Government taxes and subsidies are denoted by indirect taxes and subsidies, respectively. Operating surplus is represented by the net operating surplus.

For the price variables, output price is represented by an output deflator. Terms of trade are constructed by dividing the export price by the import price. All nominal variables are converted into 2000 constant prices using deflators obtained from the 2015 JIP Database.

Output and price volatilities are constructed to consider the volatility of the variables. The volatility of variable x is estimated from the standard deviation of the residuals of the regression $\Delta x_{it} = log(x_{it}) - log(x_{it-1}) = \alpha_i + \beta t + \varepsilon_{it}$, where Δx_{it} is the growth rate of variable x in log-difference while α_i, β, and ε_{it} represent the industry fixed effects, time trend, and error terms, respectively. The standard deviation of non-overlapping five-year periods is estimated based on the regression.[3] Table 1 shows the means and standard deviations of the variables used in estimation by the sampling periods.

To allow for industry heterogeneity intervening in the relationship between openness and output volatility, this study groups industries into four technology sectors following the OECD (2011). The high-technology sector comprises industries that require continuous research and a solid technological base. The medium-high-technology sector forms a core part of Japan's heavy and chemical manufacturing industries, which have been highly competitive in the global market. The medium-low-technology sector includes traditional manufacturing. The low-technology sector encompasses all other manufacturing industries that are not included in the other sectors.

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[2]The JIP Database provides annual data on 108 sectors compiled to estimate the total factor productivity of Japanese economy. The database was constructed by collaborative efforts of the Hitotsubashi University's Global COE Hi-Stat Program and the Research Institute of Economy, Trade and Industry. The database provides a comprehensive industrial data for the Japanese manufacturing industry.

[3]The study also considered a standard deviation of non-overlapping 10 years and a standard deviation of the whole sampling year. We obtained the similar results from the 10-year volatility measure over the total sample, but subsample regression is impossible for the high-technology sector due to the lack of degree of freedom.

Table 1. Variables, description, means and standard deviations (SD).

Variables	Description	Mean (SD)
Output	Per capita value adds [(GO_r-II_r)/EMP]†	3.086 (0.924)††
Output volatility	Standard deviation of the residual growth rate of output for the window of 5 years††	0.189 (0.238)
Investment	Total investment [I_GFCF_bysec_r]	12.296 (1.016)
IT investment	IT investment [I_IT_r]	10.023 (1.688)
Capital quality	Indices of capital quality [IDX_KQ]	0.964 (0.120)
Employment	Number of workers [EMP]	11.888 (1.170)
Labor quality	Indices of labor quality [IDX_LQ]	0.957 (0.083)
Openness	Share of exports and imports in output [(EX_r+IM_r)/GO_r]	0.006 (0.211)
Terms of trade	Export price/Import price [P_ex/P_im]	1.466 (7.227)
Output price	Output deflator [P_GO]	1.162 (0.977)
Price volatility	Output deflator (P_GO)	0.082 (0.091)
Government tax and subsidy	Indirect taxes and subsidies [TXSP]	11.397 (1.276)
Operating surplus	Operating surplus [OS]	13.760 (0.848)
Openness*Price volatility	Interaction between openness and price volatility	-0.001 (0.024)

Note: †Denotes variable names in JIP database. ††The volatility of variable x is estimated from standard deviation of residuals of regression: $\Delta x_{it} = log(x_{it}) - log(x_{it-1}) = \alpha_i + \beta t + \varepsilon_{it}$, where Δx_{it} is growth rate of variable x in log-difference, and α_i, β and ε_{it} represents industry fixed effects, time trend and error terms, respectively. ††Statistics are based on actual variables used in estimation. All variables are taken log except variables in volatility and indices.

The sample years are classified as before and after 1985, when the PA occurred, during which the top five economies agreed to depreciate the U.S. dollar against the Japanese yen. The PA is considered a turning point in the Japanese economy. After the PA, Japanese manufacturers not only automated production processes with significant investments but also migrated to foreign countries to cope with the rapid appreciation of the currency and eroding price competitiveness.

The Japanese manufacturing industry grew rapidly and steadily due to the expanding international trade until 1985. However, after the regime change in 1985, the industry became increasingly volatile to business cycles and external shocks. Thus, we expect that openness increased its impact on output volatility after 1985.[4]

3. EMPIRICAL RESULTS

3.1. Relationship between Openness and Output Volatility

To determine the basic relationship between openness and output volatility in the Japanese manufacturing industry, we regress output volatility on a set of explanatory variables.

The basic model includes output, investment, employment, labor quality, terms of trade, output price, and openness, which is the variable of focus. The model is run against two subsamples, namely, the samples before and after 1985 PA.

The estimated coefficient of openness on output volatility is significantly positive in the full sample. However, the estimate before the PA is negative, despite being insignificant, and it becomes significantly positive after the PA. The estimation results indicate a reversal in the relationship between openness and output volatility after the PA.

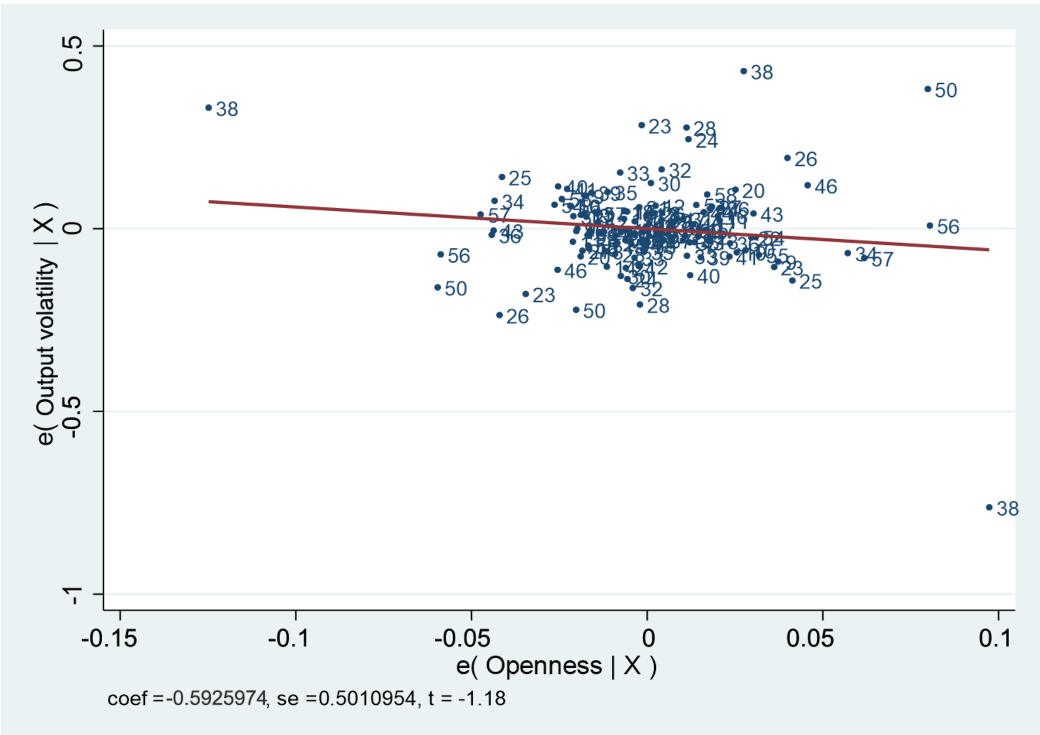
[4]The sample is classified into before and after the burst of the asset bubble in 1990, but the regime change is less apparent than that under the PA. Nevertheless, estimation results show that the openness-output volatility nexus changes from negative to positive in 1990. The sample is also classified into before and after the bank run in 1995, but the regime change is not apparent than the other classifications.

Table 2. Basic estimation for the relationship between openness and output volatility for the Japanese manufacturing industry (Dependent variable: Output volatility).

Variables	Model 1 (Total sample)	Model 2 (Before 1985)†	Model 3 (After 1985)
Log (Output)	-0.115 (0.113)	-0.542*** (0.203)	0.025 (0.075)
Log (Investment)	-0.012 (0.026)	0.026 (0.048)	-0.077** (0.035)
Log (Employment)	-0.060 (0.053)	0.244 (0.184)	-0.069 (0.061)
Labor quality	-0.386* (0.220)	0.261 (1.388)	0.059 (0.271)
Openness	0.178* (0.091)	-0.593 (0.501)	0.166* (0.094)
Terms of trade	0.000 (0.001)	0.001 (0.001)	0.053 (0.044)
Output price	0.268*** (0.068)	0.100 (0.209)	0.385*** (0.054)
Constant	1.515*** (0.712)	-1.728 (2.473)	1.364 (0.915)
R^2	0.254	0.160	0.342
N	445	136	309

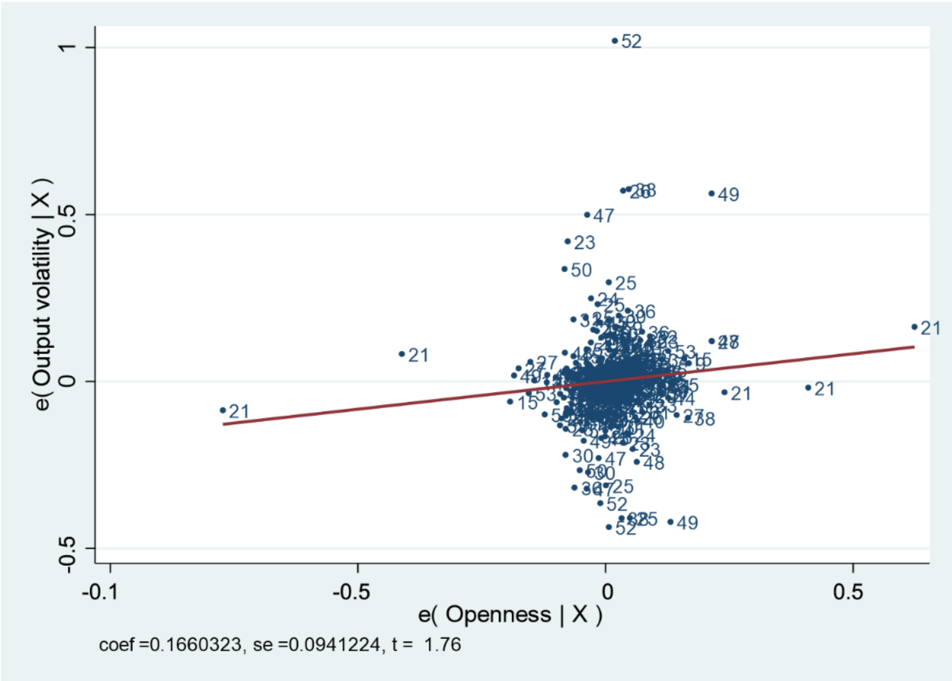
Notes: Panel fixed effect is estimated by utilizing the within estimator. Robust standard errors are in parentheses. ***, **, *Significant at 1%, 5% and 10% level, respectively. †Total sample is divided into before and after the Plaza accord in 1985 in which Top 5 economies agreed to depreciate US dollar.

To visually show the relationship between openness and output volatility, we present in Figure 1 an added-variable plot to a panel fixed effects model. The plots are based on the estimations of the fixed effects panel models reported in Table 2. The plots show a clear negative correlation between openness and output volatility before 1985 and a positive correlation thereafter, although the correlation is insignificant. Obviously, industry heterogeneity intervenes in the relationship. To address industry heterogeneity, we classify the sample into four subsamples based on technology level.[5]



a) Before 1985 of the plaza accord

[5]Section 3.2 delivers estimation results from the four technology subsamples.



b) After 1985 of the plaza accord

Figure 1. The relationship between openness and output volatility for the Japanese manufacturing industry (Subsample by period).

Note: Plot A and B are based on Model 2 and 3 in Table 2, respectively.

Our results suggest that openness reduced output volatility when the Japanese manufacturing industry grew rapidly and steadily prior to 1985. During the high-growth period, the manufacturing sector expanded continuously, along with ever-growing manufacturing exports. Growing exports were supported by increasing imports under a stable exchange rate regime. Thus, the industry's growing openness led to steady output growth, resulting in a negative relationship between openness and output volatility. However, the stabilizing impact of openness on output growth disappeared after 1985. After the PA, the Japanese manufacturing industry began experiencing a depression for the first time after the oil shocks in the 1970s. The industry plunged into a deep and prolonged recession after the burst of the bubble in the early 1990s and became more volatile to business cycles than before.

The clear break in this relationship implies that the impact of openness on output volatility depends on the economic regime that prevails in the economic circumstances. Our results are aligned with mixed findings on the relationship between openness and output volatility observed in previous studies that explored the impact of trade, growth, and development on volatility at the industry level (Giovanni & Levchenko, 2009; Imbs, 2007; Koren & Tenreyro, 2007). These studies suggest that the relationship between volatility and openness can differ at the industry level within a country from the aggregate country level. Our results are particularly significant because they are derived within the same industry in a country.

Regarding the control variables, output has a significantly negative impact on output volatility in the subsample before 1985, whereas investment has a significantly negative impact on output volatility in the subsample after 1985. This result indicates that output grew without significant turbulence before the PA, and investment helped firms reduce output volatility after the PA.

Employment has an insignificant effect on output volatility. This result suggests that the Japanese manufacturing industry has maintained employment at a stable level throughout its business cycles. The terms of trade also have an insignificant effect on output volatility. It underscores the main characteristic of the Japanese manufacturing industry, which tries to keep export prices at a stable level relative to import prices.

Meanwhile, labor quality has a significantly negative impact on output volatility in the total sample, implying that the quality of human capital helps the manufacturing industry avoid the brunt of an economic recession, which is the main reason for output volatility. However, the variable is estimated to be insignificant in the two subsamples.

Output prices exert a significantly positive impact on output volatility in the sample after 1985 but have an insignificant impact in the sample before 1985. This result suggests that an increase in prices greatly affected output volatility after the PA. Additionally, output prices have a significantly positive impact on output volatility in the total sample.

To check the robustness of the relationship observed in the total sample, we add various variables accounting for output volatility to the basic model. Table 3 reports the coefficient estimates for the robustness check.

Table 3. Robustness check of the relationship between openness and output volatility for the Japanese manufacturing industry (Dependent variable: Output volatility).

Variables	Model					
	4	5	6	7	8	9
Log (Output)	-0.074 (0.102)	-0.071 (0.099)	-0.072 (0.103)	-0.072 (0.102)	-0.054 (0.102)	-0.049 (0.101)
Log (Investment)	0.005 (0.026)	-0.003 (0.031)	0.001 (0.026)	0.006 (0.026)	-0.012 (0.027)	-0.013 (0.027)
Log (Employment)	-0.009 (0.052)	-0.009 (0.053)	-0.007 (0.047)	-0.007 (0.053)	0.007 (0.051)	0.006 (0.052)
Labor quality	-0.058 (0.259)	-0.100 (0.264)	-0.078 (0.329)	-0.058 (0.257)	0.050 (0.275)	0.055 (0.276)
Openness	0.160** (0.070)	0.163** (0.069)	0.164** (0.076)	0.160** (0.071)	0.151* (0.076)	0.133 (0.079)
Terms of trade	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.000 (0.000)	0.000 (0.001)	0.000 (0.001)
Output price	0.330*** (0.077)	0.334*** (0.074)	0.329*** (0.079)	0.332*** (0.077)	0.355*** (0.079)	0.357*** (0.080)
Government tax and subsidy	-0.066** (0.026)	-0.066** (0.026)	-0.068** (0.029)	-0.067** (0.026)	-0.045* (0.026)	-0.044* (0.026)
Capital quality		-0.071 (0.156)				
Log (IT investment)			0.004 (0.023)			
Log (Operating surplus)				-0.005 (0.007)		
Price volatility					0.363** (0.168)	0.403** (0.172)
Openness*Price volatility						0.523 (1.037)
Constant	0.942 (0.670)	0.986 (0.663)	0.961 (0.717)	0.969 (0.663)	0.501 (0.661)	0.483 (0.659)
R^2	0.274	0.275	0.274	0.275	0.288	0.288
N	436	436	436	436	436	436

Note: Refer to the notes to Table 2.
***, **, *Significant at 1%, 5% and 10% level, respectively.

Government taxes and subsidies are added as a proxy for government intervention to fine-tune the business cycles of the manufacturing industry. Government intervention has a significantly negative impact on output volatility. This result suggests that the Japanese government has actively engaged with the industry to address the challenges of business cycles and reduce output volatility.

Neither capital quality nor IT investment significantly influences output volatility. This result suggests that the characteristics of capital do not affect output volatility. Operating surplus is added to check whether an industry with financial resources can mitigate output volatility. The coefficient estimates are insignificant.

Price volatility has a significantly positive effect on output volatility. Notably, output price, which is included as a basic variable, still has a significantly positive influence on output volatility. This finding suggests that price and its changes are among the main causes of output volatility in Japan's manufacturing industry. However, the impact of openness does not interact with price volatility because the interaction variable between openness and price volatility is estimated to be insignificant.

3.2. Subsample Relationship between Openness and Output Volatility

To investigate industry heterogeneity intervening in the relationship between openness and output volatility, we classify the sample by technology level. The number of observations in the high-technology sector before 1985 is too small, with 13 observations, so it is combined with the medium-high technology sector and designated as the higher-technology sector. The basic model is estimated for the two sampling periods, and Table 4 reports the coefficient estimates.

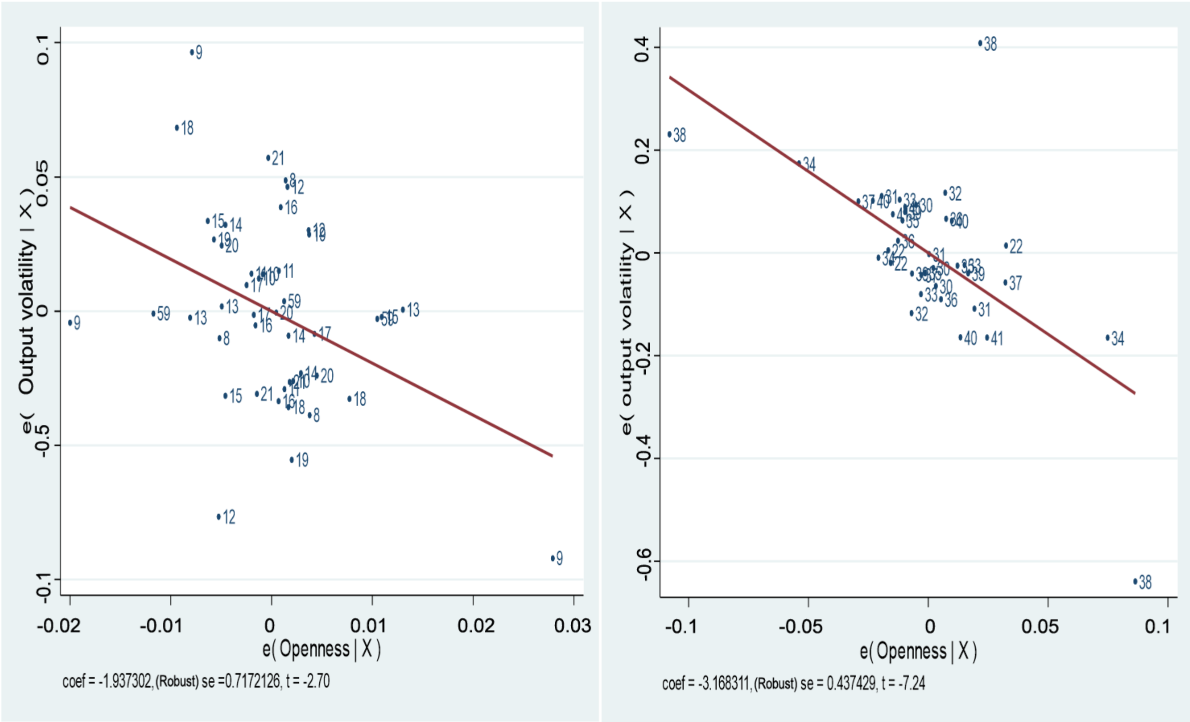
Table 4. Estimation for the relationship between openness and output volatility for the Japanese manufacturing industry by technology level (Dependent variable: Output volatility).

Variables	Model						
	Before the Plaza Accord in 1985			After the Plaza Accord in 1985			
	Low -tech.	Medium-low tech.	Higher tech.†	Low -tech.	Medium-low tech.	Medium-high tech.	High-tech.
	10	11	12	13	14	15	16
Log (Output)	-0.383 (0.224)	-1.135** (0.458)	-0.664** (0.251)	-0.232*** (0.063)	0.039 (0.193)	0.028 (0.155)	0.368 (0.277)
Log (Investment)	0.093*** (0.028)	0.053 (0.033)	-0.069 (0.123)	0.045* (0.023)	-0.076** (0.03)	-0.270* (0.145)	-0.000 (0.149)
Log (Employment)	-0.106 (0.098)	-0.637 (0.434)	0.243 (0.196)	-0.131*** (0.037)	0.020 (0.135)	0.083 (0.118)	-0.740** (0.252)
Labor quality	0.541 (0.680)	3.065 (2.732)	-0.870 (1.456)	-0.236 (0.306)	0.560 (0.894)	0.858 (0.534)	-1.098 (0.940)
Openness	-1.937** (0.717)	-3.168*** (0.437)	1.585*** (0.858)	0.131*** (0.035)	0.338 (0.27)	-0.443 (0.418)	0.151 (0.397)
Terms of trade	0.011*** (0.002)	-0.001* (0.000)	0.039 (0.066)	0.001 (0.027)	-0.038 (0.066)	-0.092 (0.085)	0.138 (0.121)
Output price	-0.067 (0.143)	-0.611 (0.429)	0.170*** (0.309)	0.217** (0.073)	0.257** (0.115)	0.780*** (0.218)	0.584 (0.367)
Constant	1.021 (1.818)	8.655 (5.293)	0.442 (2.430)	1.915** (0.672)	0.169 (2.420)	1.09 (1.962)	8.424** (3.131)
R^2	0.412	0.581	0.360	0.324	0.383	0.473	0.497
N	45	38	53	90	78	89	52

Note: †The number of observations in the high technology sector before 1985 is too small with 13, so it is combined with the medium-high technology sector. For others, refer to the notes to Table 2. To investigate industry heterogeneity existing in the relationship between output volatility and openness, the industries are grouped into four technology sectors following the OECD (2011).
***, **, *Significant at 1%, 5% and 10% level, respectively.

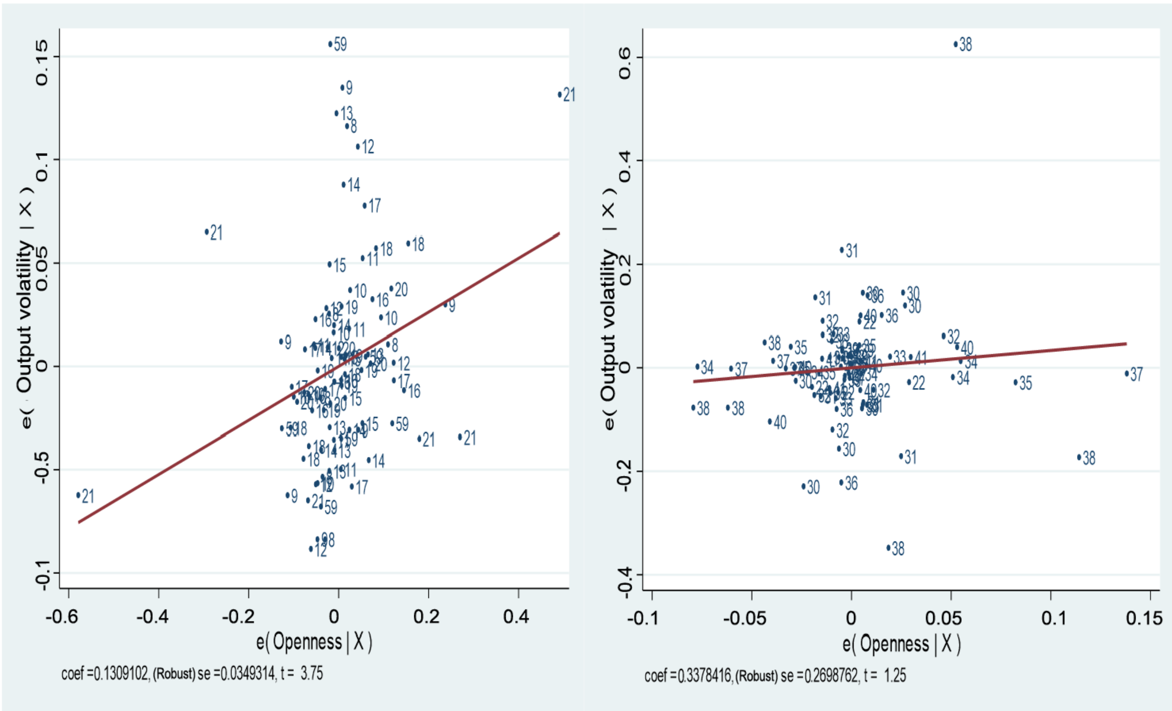
Estimation results from the sample divided by technology level show that openness decreases output volatility significantly for the two low-technology sectors before the PA but increases it afterward. However, openness increases the volatility of the higher-technology sector before the PA and does not affect it significantly after the PA.

To visually show the relationship between openness and output volatility at technology subsamples, we present in Figure 2 an added-variable plot to a panel fixed effects model. The plots are based on the estimations of the fixed effects panel models reported in Table 4. The plots show a clear negative correlation between openness and output volatility before 1985 and a positive correlation thereafter for the low-technology sectors. However, they show a clear positive correlation between the two variables before 1985 and no significant correlation thereafter for the high-technology sectors.



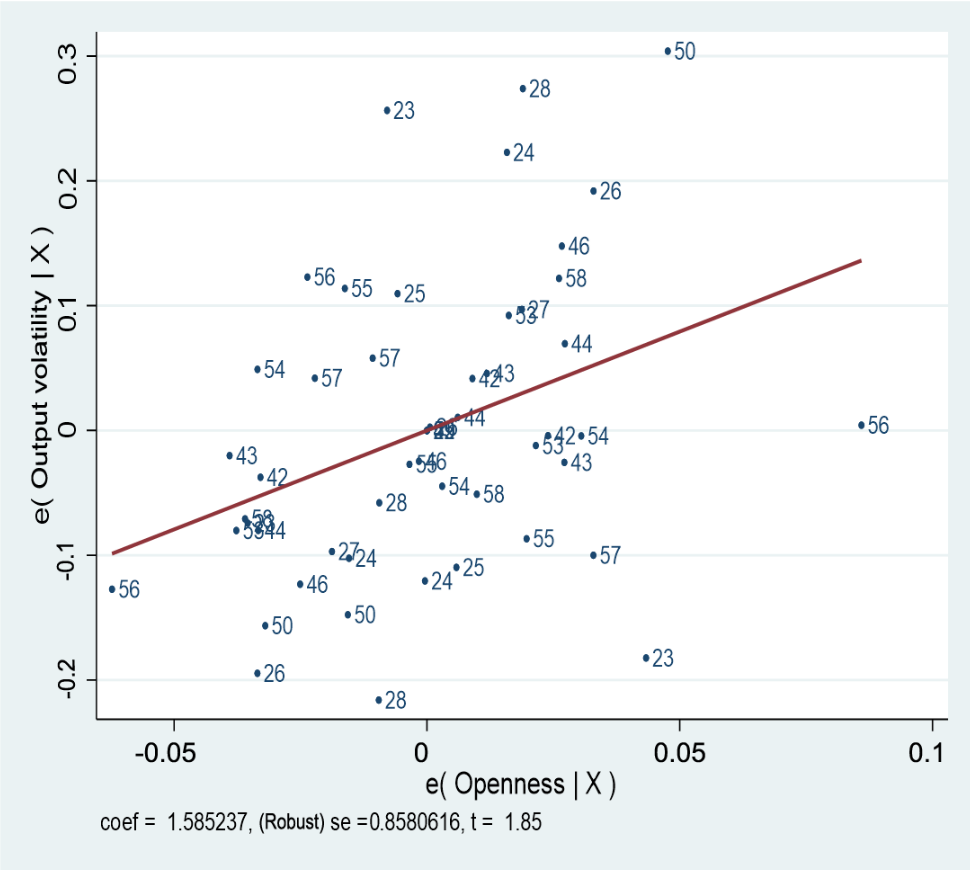
Low-technology sector Medium-low technology sector

a) Lower technology sectors before 1985

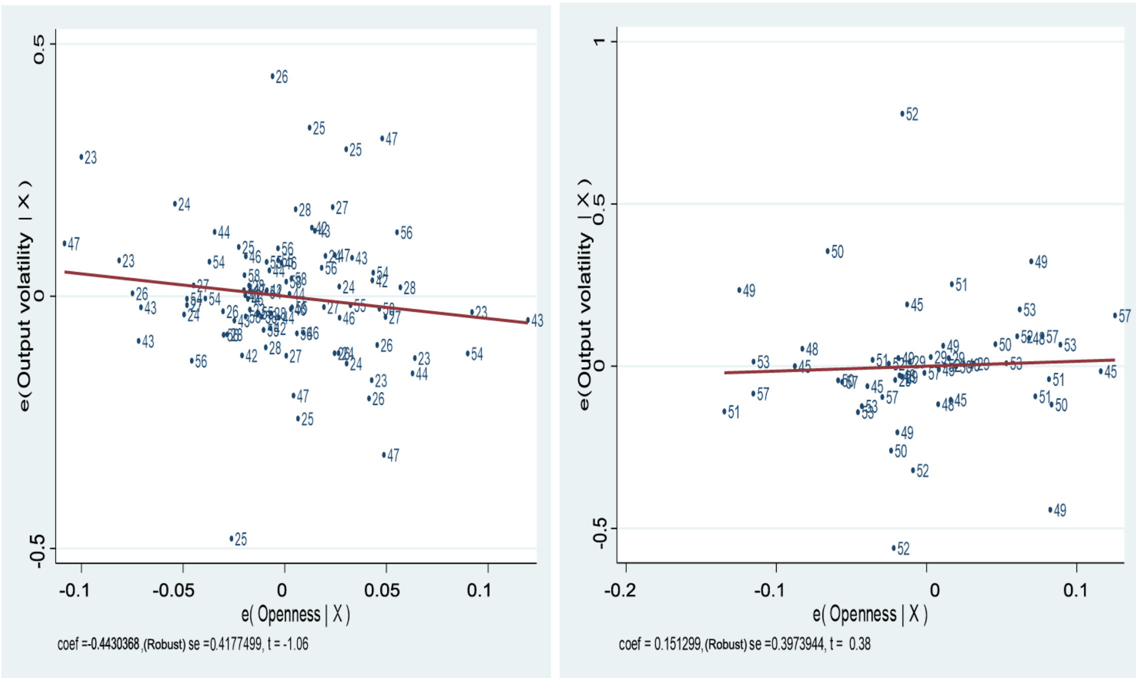


Low-technology sector Medium-low technology sector

b) Lower technology sectors after 1985



c) Higher technology sector before 1985



Medium-high technology sector High-technology sector

d) Higher technology sector after 1985

Figure 2. The relationship between openness and output volatility for the Japanese manufacturing industry by technology level and period.

Notes: Plots are based on estimations in Table 4.

The low-technology sectors grew rapidly, and their growth was trade-oriented and likely exposed to external risks. However, trade openness decreased their output volatility. This suggests that they can diversify their markets in the global market, which reduces the risk of demand volatility associated with focusing on the domestic market.

These diversification effects outweighed the increased risks arising from exposure to foreign shocks. They also did not experience major shocks that disrupted their sales during the high-growth period from the 1970s until the present. Growth during this period was steady and stable, without significant disruptions to production. Moreover, their risk-averse approach to planning and expanding production also helped them become less vulnerable to external shocks. This reflects a key characteristic of the Japanese manufacturing industry, which prefers stability over change.

The 1985 PA changed economic environment for Japanese manufacturers; they witnessed eroding competitiveness edge in the international market with greatly appreciated Japanese currency especially for lower technology sectors and exposed themselves to increased domestic risk with a creation of asset bubble and its burst and ensuing depression. As a result, openness significantly magnified output volatility for the low-technology sectors, especially for the resource-scarce low-technology sector. This affected growth of the sectors severely.[6]

Meanwhile, the high-technology sectors led the internationalization of the Japanese manufacturing industry. Their engagement in overseas markets was massive and explosive since the 1970s, which increased exposure to foreign shocks. This was evident during the 1970s when two oil shocks and subsequent depressions prompted a shift away from resource-driven and energy-intensive manufacturing toward productivity-driven and energy-saving manufacturing. External shocks disrupted production and caused increased volatility as trade openness further expanded. High-technology manufacturing products are more vulnerable to business cycles because their exports consist of durables and investment goods. After restructuring themselves, they continued to grow fast, opening themselves greatly until the 1985 PA, which exposed them to foreign shocks greatly as well.[7]

After the PA, however, openness did not significantly affect output volatility for the high-technology sectors because their growth in the export market slowed down as their price competitiveness was weakened.[8]

Regarding the control variables, output decreases volatility for the medium-low technology sector before 1985, and for the low-technology sector after 1985. Investment increases volatility for the low-technology sector during the entire sampling period and decreases volatility for the two medium-technology sectors after 1985. Employment decreases volatility for the low- and high-technology sectors after 1985. Terms of trade have positive effects on volatility for the low-technology sector but decrease it for the medium-low technology sector before the PA. Output price increases output volatility for the higher-technology sector before the PA and for all the technology sectors except for the high-technology sector afterward.

4. CONCLUSIONS

This study investigates the relationship between trade openness and output volatility in the Japanese manufacturing industry. It explores whether this relationship depends on the underlying economic environment and industry heterogeneity in technology levels. After estimating volatility using the residual approach, the study applies a fixed-effect model to the industry panel.

This study adds to the limited existing industrial research that has investigated the relationship between openness and volatility, shedding light on industry heterogeneity influencing this relationship. The study also contributes to understanding the impact of historical multilateral trade agreements from a volatility perspective.

Estimation results show that openness significantly increased output volatility for the total sample. When the sample is divided into before and after the 1985 PA, openness decreased output volatility before the PA despite its impact being insignificant, and openness significantly increased output volatility after the PA. This suggests that the

[6]Per capita real output grew by 3.18% and 0.74% annually for the low-technology sector before and after the PA, respectively, and by 2.67% and 0.60% for the medium-low technology sector before and after the PA, respectively.

[7]Estimation shows that output expansion absorbed about 42% of output volatility for the higher-technology sector before the PA (see Table 4).

[8]This might affect the growth of the sectors. The output grew by 9.77% and 3.37% annually for the medium-high technology sector before and after the PA, respectively, and by 19.96% and 9.98% for the high-technology sector before and after the PA, respectively.

openness-volatility relationship reversed from negative to positive after the PA. Openness stabilized output volatility before the PA but increased volatility afterward.

Regarding control variables, output had a negatively significant effect before the PA. Investment and employment had an insignificant impact, and the terms of trade had a positively significant impact after 1985. Output price increased volatility, except for the sample before the PA. Government taxes and subsidies lowered volatility for all models, except for models including price volatility. Price volatility significantly increased output volatility, but it did not interact with openness.

When the sample is divided by technology level, openness decreased output volatility significantly for the two low-technology sectors before the PA but increased it afterward. However, openness increased volatility significantly for the high-technology sectors before the PA, but its impact became insignificant afterward.

Our results show that the economic environment significantly affects the openness–volatility relationship. The Japanese currency appreciated greatly after the PA, and an asset bubble was created and burst in 1990, followed by long-lasting deflation. In this regard, the results suggest that the manufacturing industry has suffered from increasing volatility after the PA and has not been as active as before in pursuing the world market. The tendency that Japanese manufacturers prefer stability to variability also influenced their response to increased volatility. Their increased domestic orientation contributed to the sluggish growth of the Japanese manufacturing industry after the PA.[9]

The lower-technology manufacturing sectors experienced reduced output volatility through trade openness before the PA; however, they bore the brunt of increased volatility from openness after the PA. As a result, they became less enthusiastic about international trade when subjected to increased volatility after the PA. Meanwhile, the higher-technology manufacturing sectors actively pursued growth in the global market by taking increased risks from foreign shocks before the PA. Their continued growth and dominance in the world market could serve as a hedge against increased volatility risks. Furthermore, the risks they faced primarily stemmed from business cycles that affected global manufacturers equally, such as the oil shocks in the 1970s. However, their export-oriented growth slowed significantly when their competitiveness eroded due to the appreciation of the Japanese yen after the PA.

Our study shows that the impact of openness on output volatility depends on the exchange rate regime and technology level. A reversal of the openness-volatility relationship occurred after the PA. However, the reason why the relationship is nonlinear across the technology sectors is not clear from this study. Further research should investigate the cause of the nonlinearity in the relationship.

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[9]For the Japanese manufacturing industry, per capita real output grew by 6.62% and 3.19% per annum before and after the 1985 PA, respectively.

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