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Hysteresis in Japanese Export Market: A Dynamic Random-Effect Probit Approach to Panel Data of Japanese Machinery-manufacturing Firms*

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Abstract
We estimate the hysteresis effect in export participation decision based on rich panel data of Japanese machinery-manufacturing firms from 1994 to 2015. We find that the "observed" hysteresis effect, difference between the probability of export for the firms that exported in the previous year and the probability of export for the firms that did not export in the previous year, is quite large (0.904 for machinery-manufacturing sector as a whole) Using the estimates of dynamic random-effects probit model, we calculate the degree of "genuine" hysteresis Then we find that the "observed" hysteresis in part reflects spurious effects that are caused by both observable (firm size) and unobservable firm characteristics that tend to persist over time. The genuine hysteresis effect, free from spurious effects, is much smaller than the observed one, but the magnitude of genuine hysteresis still exceeds 0.5.

Keywords: export, extensive margin, hysteresis effect, dynamic probit model
JEL classification: E44, F14, O30

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1. Introduction

Sunk-cost hysteresis hypothesis of export states that hysteresis or state dependence in exports may be due to the sunk costs in entering the export market at the firm level, as was theoretically suggested by Dixit (1989), Baldwin(1990), Baldwin and Krugman (1989) and others. Following the theoretical models a number of papers have tested the sunk-cost hysteresis hypothesis. For example, Bernard and Jensen (2004) find that past exporters are more likely to re-export and plants are likely to export in consecutive years based on the U.S. manufacturing plant data. Roberts and Tybout (1997), Bernard and Wagner (2001) and Baldwin and Gu (2003) are empirical studies in line with the sunk-cost hysteresis hypothesis literature. They find that the decision to export is closely related to sunk cost and past experience of export.

Testing procedure to detect for the possible presence of entry costs is simply to look at the effects of exporting in the previous period on exporting today in dynamic exporting model. However, observed differences in exporting behavior for past exporters and non-exporters are misleading about "genuine" hysteresis. The magnitude of genuine hysteresis is defined as the difference between (1) the export persistence rate were all firms to have exported in the previous period and (2) the entry rate to the export market were all firms not to have exported in the previous year. Certain types of firms are more likely to have a history of previous exporting behavior than others and these characteristics tend to persist over time. The association between past and present exporting behavior just described therefore in part reflects a cross-time correlation of characteristics rather than the pure effects of past exporting.

The purpose of this study is to estimate the genuine hysteresis of export for Japanese firms by estimating dynamic random-effects probit model of exporting behavior. The basic data we use in this study come from the *Basic Survey of Japanese Business Structure and Activities* (BSJBSA) of Ministry of Economy, Trade, and Industry of the government of Japan. The virtue of this comprehensive survey is to include unlisted SMEs as well as listed large firms. In fact, this survey covers enterprises with 50 or more employees and whose equity capital is over 30 million yen (equivalent to about 300,000 dollars). It provides the time series of financial statement and related information of 62,265 firms (643,699 firm-year observations) over the period after 1991.[1] We will analyze the exporting behavior of firms based on this dataset from 1994 to 2015. In what follows, we focus on the machinery-manufacturing firms since these firms play a major role in

[1] The surveys in 1992 and 1993 are not available, so we can use the survey only after 1994 in succession. The detailed data structure, for example number of samples and the panel structure are presented in Table A1 in Appendix to this paper.

exporting activities.[2]

Let us preview our main findings. We specify the export market participation decision to be explained by firm size, price-cost margin, liquidity ratio and the firm's status in the export market in the previous period and then estimate it by the dynamic random-effects probit model. We find that the firm's status in the export market in the previous period is an important factor to determine the current status in export market. However, the genuine hysteresis effect is much weaker than the observed hysteresis and the association between past and present exporting behavior in part reflects a cross-time correlation of firm size and unobservable firm characteristics. In particular ignoring unobservable firm characteristics leads to serious overestimation of genuine hysteresis.

The paper is organized as follows. Section 2 describes the export behavior of machinery-manufacturing firms based on our data set. Section 3 characterizes the exporting behavior of a firm in partial equilibrium context. We discuss the empirical results in Section 4. Finally, section 5 concludes.

2. Description of Japanese Export Markets for Machinery-Manufacturing Firms

We describe major characteristics of Japanese export markets for machinery-manufacturing firms in the period of 1994 to 2015, using the panel data of BSJBSA. Figure 1 indicates the percentage change of the exporting firms in machinery-manufacturing industry over our sample period. We find that the proportion of exporting firms is 36.0% in 1994, but after a temporary drop due to financial crisis in the Japanese economy in 1997, it has steadily increased to 47.7% in 2015. Figure 2 shows the number of exporting firms, total export value and the average export value, all being indexed as 1.00 in 2005. As can be seen from the figure, total export value reached its peak in 2007 and then turned to a decline due to the Global Financial Crisis in 2008. It should be noted, however, that the number of exporting firms is relatively stable over the sample period even during the Global Financial Crisis where a big turnover in export value is observed. This means that the fluctuation of the total export value over time is mainly due to quantitative adjustment of the export volume by exporting firms (change in *intensive margin of export*) rather than the firm's behavior of new entry to or exit from the export market (change in *extensive margin of export*). This may be one of the important reasons why there is some hysteresis effect of exporting behavior.

[2] In this data set more than 50% of the exporting firms in manufacturing sector is machinery-manufacturing firms and their export value are far in excess of 80% of total export value of manufacturing sector on average from 1994 to 2015.

Table 1 shows dynamic properties of entry and exit behavior of machinery-manufacturing firms over time. About 60 percent of non-export firms in the initial period stay away from export market during the whole sample period and 40 percent of non-export firms in the initial period enter the export market as least once in the sample period. Nearly 13 percent of non-export firms in the initial period entered the export market repeatedly. On the other hand, 67 percent of export firms in the initial period remains the export market for the whole sample period and 33 percent of export firms exit from the export market at least once during the sample period. About 10 percent of export firms in the initial period exited the export market repeatedly. This dynamic behavior of non-export firms and export firms hints that hysteresis in the export market coexist with frequent entry and exit behavior of firms.[3]

Table 2 presents the proportion of exporting firms of machinery-manufacturing sector by year and individual industry: general machinery, electrical machinery and transportation equipment industry from 1994 to 2015. These values in the table can be interpreted as empirical probability of exporting in each year. For example, as is shown in column (1), the probability that firms export in machinery-manufacturing sector as a whole is 0.396 in 1994 and it increases up to 0.514 in 2015.[4] The bottom row shows the average of these probabilities for the whole sample period. They are 0.454, 0.559, 0.395 and 0.383 for total machinery-manufacturing sector, general machinery, electrical machinery and transportation equipment industries, respectively. We call these numbers "observed" probability of exporting.

Now we show some dynamic properties of export market participation decision by individual firm. Table 3 presents the dynamics of entry into or exit from the export market. Columns (1) to (4) indicate the number of firms corresponding to the entry or exit activities. For example, Column (1), labeled e_{00}, indicates the number of non-exporting firms in the corresponding year that were not exporting in the previous year. Column (3), labeled e_{10}, indicates the number of exporting firms in the corresponding year that were not exporting in the previous year. As for columns (2) and (4), same definitions might be applied.[5] For example, we have 1,936 sample firms in 2000 and among them 86 firms newly entered the export market this year and 42 firms exited the export market during

[3] The same kind of tables by sub-industry are provided in Appendix (Table A6a to A6c).

[4] The values in the table are calculated based on the sample adjusted for the dynamic analysis. Accordingly, they are slightly different from the values in Figure 1. See Appendix for details.

[5] Probability of exporting is calculated as $(e_{10} + e_{11}) / (e_{00} + e_{01} + e_{10} + e_{11})$. The values from Table 3 are slightly different from the corresponding percentages in Table 1 because we eliminate the starting year of each firm in Table 3.

1999 to 2000.

Based on these numbers we can calculate the "observed" entry probability $P(1|0)$ and exit probability $P(0|1)$ each year as follows.

$$P(1|0) = e_{10}/(e_{10} + e_{00}) \quad (1)$$

$$P(0|1) = e_{01}/(e_{01} + e_{11}) \quad (2)$$

As is shown in columns in (6) and (7), the "observed" entry or exit probabilities in the sample period are about 0.050 and 0.046, respectively. The persistent probability is 1-0.046=0.954. The "observed" hysteresis effect is defined as the difference between the probability of export for the firms that exported in the previous year and the probability of export for the firms that did not export in the previous year (entry probability). The "observed" hysteresis effect is 0.954 – 0.050 = 0.904. We find that strong hysteresis effect is observed in the exporting decision. It should be noted, however, that this "observed" hysteresis does not necessarily capture the "genuine" hysteresis effect since export firms have large firm size, measured by total asset and large firm size tends to persist over time. Then the association between past and present exporting behavior simply reflects a cross-time correlation of firm size rather than the pure hysteresis effect. Therefore it is important to distinguish the genuine hysteresis from the observed hysteresis. Estimation of the dynamic random-effects probit model of exporting behavior enables us to obtain the degree of genuine hysteresis.[6]

3 Basic model of exporting behavior

We construct a market equilibrium model of firms that sell their products in both domestic and overseas markets. Our model is in line with the recent trade theory developed by Melitz (2003), Melitz and Ottaviano (2008) and Bernard et al. (2003) that stresses firm heterogeneity. Consider a profit-maximizing firm that sells its product in both domestic and overseas markets. The firm faces a downward-sloping demand curve in domestic and overseas market, respectively. We assume that there are *N* firms in the market. Downward-sloping demand curve in overseas market is given by

[6] The dynamic random-effect probit model has been often adopted in the analysis of the hysteresis in labor market. For example, see Boskin (1974) for occupational choice, Boskin and Nord (1975) and Immervoll et al. (2015) for the state dependence in social aid and Hall (1973) for turnover in the labor force.

$$Q_E = E\left(\frac{P_E}{eP_w}\right)^{-\eta} \quad (3)$$

where Q_E: demand for exports,

P_E: export price on a yen basis

P_w: world price on a dollar basis

e : exchange rate (yen per dollar)

η : price elasticity of overseas demand and

E : factors that shift export demand

The inverse demand curve is expressed as

$$P_E = eP_W B Q_E^{-\frac{1}{\eta}}$$
$$B = E^{\frac{1}{\eta}} \quad (4)$$

Similarly, downward-sloping demand curve in domestic market and the inverse domestic demand curve are given by eqs. (5) and (6), respectively.

$$Q_D = HP_D^{-\theta} \quad (5)$$

where Q_D:domestic demand,

P_D:domestic price,

θ: price elasticity of domestic demand and

H:factors that shift domestic demand.

$$P_D = JQ_D^{-\frac{1}{\theta}} \quad (6)$$

where $J = H^{\frac{1}{\theta}}$.

The profit of the i-th firm is defined by (7).[7]

[7] As for the decision of intensive margin of export, the profit of the i-th firms is maximized with respect to overseas sales (Q_{iE}) and domestic sales (Q_{iD}). See Ogawa and Tokutsu (2015) for the quantitative analysis of the intensive margin of export in line with the firm's export model developed here.

$$\pi = p_E Q_{iE} + p_D Q_{iD} - C_i(T_i, r_i, w_i, p_{Mi})(Q_{iE} + Q_{iD}) - \phi(A_i) Q_{iE} - F_i \qquad (7)$$

$$P_E = eP_W B \left(\sum_{i=1}^{N} Q_{iE} \right)^{-\frac{1}{\eta}}$$

$$P_D = J \left(\sum_{i=1}^{N} Q_{iD} \right)^{-\frac{1}{\theta}}$$

where $C_i(T_i, r_i, w_i, p_{Mi})$ is a unit cost function with

$\frac{\partial C_i}{\partial T_i} < 0, \frac{\partial C_i}{\partial r_i} > 0, \frac{\partial C_i}{\partial w_i} > 0, \frac{\partial C_i}{\partial p_{Mi}} > 0,$

T_i: total factor productivity (TFP),

r_i: rental cost of capital,

w_i: wage rate,

p_{Mi}: material price,

$\phi(A_i)$: unit trading cost with $\phi'(A_i) < 0$,

A_i: total assets and

F_i: start-up cost of export.

It is assumed that production technology is linearly homogeneous, so that the unit cost function does not depend on the level of output. The trading cost includes tariff and transportation cost. We assume that the unit trading cost is a decreasing function of firm size, measured by total assets.[8] We assume that a firm pays fixed cost F_i to start up export.

A firm exports if current revenue of export is greater than cost or

$$p_E Q_{iE} - C_i(T_i, r_i, w_i, p_{Mi}) Q_{iE} - \phi(A_i) Q_{iE} - F_i > 0 \qquad (8)$$

This inequality is written as

$$\left(\frac{p_E}{C_i(T_i, r_i, w_i, p_{Mi})} - 1 \right) C_i(T_i, r_i, w_i, p_{Mi}) - \phi(A_i) - \frac{F_i}{Q_{iE}} > 0 \qquad (9)$$

In other words, a firm is more likely to export when the price-cost margin

[8] Forslid and Okubo (2011) find that the unit trading cost is a decreasing function of firm size due to scale economy.

(PCM) is higher and firm size is larger.[9] Large firms attain lower unit trading cost, $\phi(A_i)$ and fixed cost per export, $\frac{F_i}{Q_{iE}}$ as export amount and total assets are positively correlated. Existence of sunk costs generates hysteresis in export markets. Once a firm enters the export market by paying fixed cost, the firm is more likely to stay in the export market. To sum up, start-up decision of export depends on firm size, measured by total assets, price-cost margin and the firm's status in the export market in the previous period. We employ a binary response model to specify the export market participation decision described above. Let us define a latent variable Y_i^* as

$$Y_i^* = f\left(A_{i,-1}, PCM_{i,-1}, Y_{i,-1}, v_i, \epsilon_i\right) \tag{10}$$

where

PCM_{i-1}: price-cost margin in the previous year,

$Y_{i,-1}$=1 if a firm exported in the previous year and 0 otherwise

v_i: unobservable firm characteristics

ϵ_i: disturbance term.

We observe

$$Y_i = \begin{cases} 1 & if\ \ Y_i^* > 0 \\ 0 & if\ \ Y_i^* \leq 0 \end{cases} \tag{11}$$

It is implicitly assumed that exporters do not face liquidity constraints in characterizing the firms' exporting behavior above. However exporters might face higher effective borrowing rate with external finance premium added on when capital market is imperfect. This is especially so for SMEs since the SMEs have less financial assets and have limited access to capital market. Recent empirical studies find that exporters might be liquidity-constrained. Amiti and Weinstein (2011) demonstrate that trade finance provided by the financial institutions played an important role in exporting behavior of Japanese listed firms. They show that bank health was important in providing trade finance with exporters and hence contributed to export increase.[10]

[9] *PCM* in this paper is defined as the ratio of output price to marginal cost, while it is usually defined as the ratio of the difference between output price and marginal cost to output price. The difference in both definitions does not change the economic characteristics of *PCM* at all.

[10] A number of researchers have examined the role of trade finance or external finance in exporting behavior. For example, see Kletzer and Bardhan (1987), Ronci (2005), Muûls (2008), Bricogne et al.(2009), Iacovone and Zavacka (2009), Feenstra et al. (2010), Haddad et al. (2010), Levchenko et al. (2010), Chor and Manova (2010) and Manova et al. (2011).

However, since it is quite difficult to construct the exact matched data between firms and lender in the survey, we extend firms' export market participation decision by including the firm health. As for the firm health variable, we use the liquidity ratio, defined as the current assets less current liabilities over total assets.

The extended export market participation decision is specified as

$$Y_i = \begin{cases} 1 & if\ \ Y_i^* > 0 \\ 0 & if\ \ Y_i^* \leq 0 \end{cases} \tag{12}$$

$$Y_i^* = f\left(A_{i,-1}, PCM_{i,-1}, LIQ_{i,-1} Y_{i,-1}, v_i, \epsilon_i\right)$$

where $LIQ_{i,-1}$ is liquidity ratio in the previous year.

4. Empirical result

4.1 Estimation of static probit model of export market participation

First of all, we present a static model of export market participation by the following discrete choice model.

$$Y_{it} = \begin{cases} 1 & if\ \ Y_{it}^* > 0 \\ 0 & if\ \ Y_{it}^* \leq 0 \end{cases} \tag{13}$$

$$Y_{it}^* = \beta_1 PCM_{it} + \beta_2 LIQ_{it} + \beta_3 \ln ASSET_{it} + v_i + w_t + u_{it}$$

As for the time-specific disturbance term w_t, we capture the time fixed effect by the constant time dummy variables. We also add two constant industry dummy variables for electrical machinery and transportation equipment with general machinery as base industry. We estimate equation (13) by random effect probit model. The estimated coefficients are presented in column (1) of Table 4.

In the static model, the estimated coefficient of *PCM* is insignificant and negative. This result is inconsistent with the prediction from the theoretical model in eq. (9) This may be attributed to our way of constructing *PCM* variable. As can be seen from equation (8) that compares the revenue and cost of export in making export participation decision, revenue and cost should pertain to export activities. However, *PCM* used in the regression is simply the ratio of total sales to total cost of individual firms, both of which include sales and cost for domestic product as well as the exported good.

Ideally, we can construct the *PCM* consistent with the definition in equation (9) as long as the export price, p_E, and unit cost, *c*, are available for each firm,. However, p_E and *c* are only available as time series index that is common to all firms in the same year. That is to say, they have only within-firm variance and do not have between-firm variance in the panel data. The variables of this type are all included in the fixed time effect (constant dummy variables) and they cannot be used as an independent explanatory variable. Therefore, we define PCM simply as the ratio of total sales to total cost for each firm by assuming that the marginal cost is equal to the average cost. Insignificant coefficient estimates of PCM might result from our somewhat imprecise measure of price cost margin in the export market.

All other coefficients are significant and have expected sign. That is to say, the firm is subject to liquidity constraint to some extent (positive coefficient for *LIQ*) and the scale of the firm promotes the entry to export market (positive coefficient for ln *ASSET*). The coefficients of two industry dummy variables are both significantly negative, indicating the probability of exporting is substantially lower for the corresponding two industries than general machinery as is seen in the "observed" probability of exporting.

Based on the estimated model, we can calculate the probability of export as follows.

$$\Pr(1|PCM, LIQ, \ln ASSET) = \Phi[\hat{\beta}_1 PCM_{it} + \hat{\beta}_2 LIQ_{it} + \hat{\beta}_3 \ln ASSET_{it}] \quad (14)$$

where $\Phi[\cdot]$ is the standard normal cumulative density function.[11] They are presented in Table 5.[12] The estimated probability of exporting for machinery-manufacturing sector as a whole is 0.366, while the corresponding "observed" probability is 0.454. Thus the probability of export is somewhat underestimated by the static model.

4.2 Estimation of dynamic random-effect probit model of export market participation

Now we estimate the genuine hysteresis effect by estimating the dynamic random-effect probit model of Skrondal-Hesketh type (Skrondal and Rabe-Hesketh, 2014) that takes account of the initial condition and unobservable heterogeneity of firms to obtain consistent estimates.[13]

$$Y_{it}^* = \beta_1 PCM_{it} + \beta_2 LIQ_{it} + \beta_3 \ln ASSET_{it} + \gamma Y_{i,t-1} + c_i + w_t + u_{it} \quad (15)$$

[11] The time and industry dummies are also taken into consideration in calculating the probability of export.

[12] Actually, the entry and exit probabilities are calculated by taking average of predictions of (14) for individual firm-year observations.

[13] The model is estimated based on the program for Stata provided by Grotti and Cutuli (2018). For detailed discussion on the initial condition, see, for example, Rabe-Hesketh and Skrondal (2013), Heckman (1981) and Wooldridge (2005).

where c_i is the firm-specific unobserved factor. Following Skrondal-Hesketh, we assume that the firm-specific unobserved factor is express as a linear function of initial values and within-firm sample averages (denoted by overbars on variables) of explanatory variables.

$$c_i = \alpha_0 + \alpha_1 Y_{i0} + \alpha_2 PCM_{i0} + \alpha_3 LIQ_{i0} + \alpha_4 \ln ASSET_{i0} \qquad (16)$$
$$+ \alpha_5 \overline{PCM}_i + \alpha_6 \overline{LIQ}_i + \alpha_7 \overline{\ln ASSET}_i + \epsilon_i$$

The estimation coefficient and corresponding marginal effect are shown in columns (3) and (4) of Table 4. The lagged status in export market is significantly positive, indicating the existence of hysteresis in export participation decision. On the contrary, *LIQ* loses its significance and ln *ASSET* is barely significant at the 10% level, while both are significant at the 1% level in the static model. This means that the exporting decision is dominated by hysteresis effect. Exporting status in the previous year raises the exporting probability by 0.4548.

As is seen from the coefficient of firm-specific unobservable factor in eq. (16), the initial export status (Y_{i0}) has significantly positive effect, indicating the positive correlation between unobserved firm-specific factor c_i and initial export status. The coefficient of initial level of ln *ASSET* is significantly negative, while that of the within-firm sample average of ln *ASSET* is significantly positive. That is to say, the former is negatively correlated with unobserved firm-specific factor and the latter is positively correlated with unobserved firm-specific factor. Combining these effects together, the firm growth, measured by total assets, is positively correlated with firm-specific unobserved factor. We will make further discussion on this point when we examine the effect of unobserved factor on the probability of entry or exit to export market.

Based on the estimated model, we can estimate the entry and persistent probability of export as follows.

$$\Pr(1|0) = \Phi[\hat{\beta}_1 PCM_{it} + \hat{\beta}_2 LIQ_{it} + \hat{\beta}_3 \ln ASSET_{it} + \hat{c}_i] \qquad (17)$$

$$\Pr(1|1) = \Phi[\hat{\beta}_1 PCM_{it} + \hat{\beta}_2 LIQ_{it} + \hat{\beta}_3 \ln ASSET_{it} + \hat{\gamma} + \hat{c}_i] \qquad (18)$$

Using eqs. (17) and (18), the degree of genuine hysteresis (GH) is calculated as

$$GH = \Pr(1|1) - \Pr(1|0)$$

(19)

Calculated probabilities are presented in Table 6 by industry. The probability of exporting in the steady state and the mean duration of the period of exporting in the steady state are also shown in Table 6. As can be seen from the table, entry probability is 0.232 for machinery-manufacturing sector. This value is much larger than the corresponding "raw" probability, 0.050 in Table 3. It is also true for exit probability. The estimated exit probability is 0.267 that is much larger than the observed "raw" probability, 0.046.

Now we compare the genuine hysteresis with the observed hysteresis. The observed hysteresis is quite high, ranging from 0.894 (general machinery) to 0.911 (transportation equipment). However, the genuine hysteresis is much lower than the observed one and ranges from 0.501 (total machinery and transportation equipment) to 0.518 (general machinery). It suggests that observed hysteresis includes spurious hysteresis that is attributable to observed and unobserved differences in characteristics across firms.

It is important to stress that genuine hysteresis is overestimated when unobservable firm-specific factors are omitted in estimating dynamic probit model. To see this, we estimate eq. (15) without c_i. The entry and exit probabilities are 0.124 and 0.155, respectively, for machinery-manufacturing sector as a whole. The genuine hysteresis is estimated as 1- 0.124 – 0.155 = 0.721. This estimate is much larger than the genuine hysteresis when the unobservable firm-specific factors are not properly taken into account. The genuine hysteresis is also overestimated for individual industries when the unobservable firm-specific factors are ignored.

Based on these probabilities, we can estimate the probability of exporting in the steady state.[14] The estimated probability of exporting in the steady state is 0.465 for machinery-manufacturing sector as a whole, while those based on the observed entry and exit probabilities is 0.517 and those based on the entry and exit probabilities without unobserved firm-specific factor is 0.445.

4.3 Unobservable firm-specific factors and export market participation: Quantitative evaluation of its importance

Finally, we examine the effect of unobservable firm-specific factors on entry and exit probabilities. Figure 3 shows the probability of export by initial export status and the level of unobserved firm-specific factor. The left panel of the figure shows the probability of export of initially non-export firms by the level of unobserved firm-specific factor and the right panel shows that of initially exporting firms by the level of unobserved firm-

[14] For the probability of exporting and the corresponding mean duration of export, see Boskin-Nord (1975). They derived the steady state probability of export from the general solution of difference equation of entry and exit probabilities and mean duration period is derived as the reciprocal of exit probability by assuming that the duration of stay of a firm in export status follows the geometric distribution.

specific factor. We divide the level of unobserved firm-specific factor into four groups by quartiles. The probability of export if the firm exports in the previous period (persistence probability) is higher for initially exporting firms than for initially not-exporting firms, irrespective of the level of the unobserved factor. For initially exporting firms, the probability of export persistence is close to unity, irrespective of the level of the unobservable factor. On the other hand, the probability of export persistence increases sharply from 0.45 to 0.73 for initially not-exporting firm as the unobserved firm-specific score increases.

As for the probability of export, it is quite low (less than 0.1) for the firms that did not export in the previous period, irrespective of the level of unobserved firm-specific factor, while it increases from 0.32 to 0.65 for initially exporting firm.

5. Concluding remarks

It is often argued that there is strong hysteresis effect in export behavior of firms. Firms do not exit from the export market even when the economic condition, such as exchange rate, changes unfavorably because of sunk cost. In this study we estimated the degree of genuine hysteresis for Japanese machinery-manufacturing firms by using rich panel data set of machinery-manufacturing firms from 1994 to 2015. Using the estimates of dynamic random-effects probit model, we calculated the degree of hysteresis by taking account of observable and unobservable firm characteristics that persist over time. Even after controlling for these spurious hysteresis, we find some hysteresis in export market participation decision due to sunk cost. However, genuine hysteresis effect is not so strong as the observed hysteresis.

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Appendix

Total number of firms in machinery-manufacturing sector in the survey is presented in Table A1 by year and by industry. We use the variables on price cost margin (*PCM*), liquidity ratio (*LIQ*) and log of total asset (ln*ASSET*). *PCM* is defined the ratio of total sales to total cost, *LIQ* is the ratio of net liquid asset (liquid asset – liquid debt) to total asset and ln*ASSET* is logarithm of the total asset. Descriptive statistics for these variables are presented in Table A5. We eliminate the firm-year observations with missing values of one of these variables. Also, upper 0.5% and lower 0.5% firms within each industry and year are eliminated as outliers.

Since our concern is the dynamic in-out decision in export market, we restricted the sample firms that have at least 10 consecutive records in the survey. As a result, the number of firms and sample period are reduced to less than 50% of the original observations. The structure of the data used in the paper is presented in Table A2. As can be seen from Table A2, the data we use is not a balanced panel. Firms with full 22-year records are dominant and they are about 44.0% of total sample firms and 53.5% in terms of sample firm-year points. See Table A3 for descriptive statistics of major variables used in the analysis.

In the survey, identical firms are sometimes, though not so often, classified as different industry during the sample period. Since we regard the industry as the firm-specific time invariant character, we classify the firm to the industry where the corresponding firms stay in most of years (practically classified by the mode of the industry code).

Table 1 Entry and exit behavior of sample firms

		(1)	(2)	(3)	(4)
		Not exporting at initial period		Exporting at initial period	
Number of times of entry	0	897	(60.2)	687	(77.8)
	1	402	(27.0)	143	(16.2)
	2	146	(9.8)	40	(4.5)
	3	37	(2.5)	11	(1.3)
	4	7	(0.5)	2	(0.2)
	5	2	(0.1)		
Number of times of exit	0	1,154	(77.4)	592	(67.0)
	1	251	(16.8)	205	(23.2)
	2	64	(4.3)	62	(7.0)
	3	17	(1.1)	21	(2.4)
	4	3	(0.2)	2	(0.2)
	5	2	(0.1)	1	(0.1)
	Total	1,491		883	

Data source: the Basic Survey of Japanese Business Structure and Activities

Table 2 Percentage of exporting firms by sub-industry

	(1) Total machinery-manufacturing	(2) General machinery	(3) Electrical machinery	(4) Trans. equipment
1994	39.6	49.6	34.9	32.2
1995	41.2	51.4	35.9	34.2
1996	43.0	53.1	37.7	36.4
1997	40.1	49.4	35.1	33.9
1998	40.4	49.4	35.1	35.1
1999	40.8	50.1	35.6	34.3
2000	43.0	52.3	38.1	36.4
2001	42.5	51.3	37.3	37.1
2002	43.3	52.6	38.6	35.9
2003	44.2	53.6	39.2	37.4
2004	45.7	54.9	40.7	39.0
2005	45.9	55.6	39.9	40.1
2006	46.1	56.9	39.9	38.8
2007	46.2	57.6	39.2	39.8
2008	46.1	58.0	39.8	37.6
2009	47.7	59.8	41.7	38.4
2010	49.5	60.8	43.9	40.5
2011	49.5	61.1	43.1	41.0
2012	50.7	62.0	44.2	42.8
2013	50.7	61.9	44.3	42.5
2014	51.3	63.3	43.7	43.3
2015	51.4	63.6	42.7	44.7
Total	45.4	55.9	39.5	38.3

Data source: the Basic Survey of Japanese Business Structure and Activities

Table 3 Observed entry and exit probability

	(1) e_{00}	(2) e_{01}	(3) e_{10}	(4) e_{11}	(5) total	(6) entry prob.	(7) exit prob.
1995	852	24	66	579	1,521	0.072	0.040
1996	933	22	63	676	1,694	0.063	0.032
1997	970	80	31	676	1,757	0.031	0.106
1998	1,039	38	55	695	1,827	0.050	0.052
1999	1,072	39	52	724	1,887	0.046	0.051
2000	1,061	42	86	747	1,936	0.075	0.053
2001	1,089	47	48	812	1,996	0.042	0.055
2002	1,129	46	61	835	2,071	0.051	0.052
2003	1,144	42	68	882	2,136	0.056	0.045
2004	1,128	36	61	918	2,143	0.051	0.038
2005	1,117	45	57	947	2,166	0.049	0.045
2006	1,132	43	57	968	2,200	0.048	0.043
2007	1,115	53	45	959	2,172	0.039	0.052
2008	1,081	51	45	924	2,101	0.040	0.052
2009	1,019	52	79	898	2,048	0.072	0.055
2010	973	29	59	923	1,984	0.057	0.030
2011	939	41	36	923	1,939	0.037	0.043
2012	893	29	43	907	1,872	0.046	0.031
2013	856	38	32	887	1,813	0.036	0.041
2014	820	32	39	858	1,749	0.045	0.036
2015	787	28	24	837	1,676	0.030	0.032
Total	21,149	857	1,107	17,575	40,688	0.050	0.046

Data source: the Basic Survey of Japanese Business Structure and Activities

Table 4 Estimation result of probit model

	(1)	(2)	(3)	(4)
	Static model		Dynamic model	
	Coefficient	Marginal effect	Coefficient	Marginal effect
Y_{-1}			2.2457 ***	0.4548 ***
			(0.0364)	(0.0166)
PCM_{-1}	-0.3643	-0.0384	-0.1711	-0.0188
	(0.2520)	(0.0266)	(0.2881)	(0.0316)
$LIQR_{-1}$	0.2889 ***	0.0305 ***	-0.0060	-0.0007
	(0.1074)	(0.0114)	(0.1280)	(0.0141)
$\ln ASSET_{-1}$	0.8821 ***	0.0930 ***	0.0979 *	0.0108 *
	(0.0357)	(0.0046)	(0.0506)	(0.0056)
$D13$	-1.6115 ***	-0.1778 ***	-0.3244 ***	-0.0366 ***
	(0.2180)	(0.0229)	(0.0646)	(0.0074)
$D14$	-2.3376 ***	-0.2542 ***	-0.3453 ***	-0.0389 ***
	(0.2194)	(0.0223)	(0.0741)	(0.0084)
Y_0			1.7925 ***	0.3259 ***
			(0.0835)	(0.0161)
PCM_0			-0.7668	-0.0843
			(0.5520)	(0.0606)
$LIQR_0$			0.2521	0.0277
			(0.1961)	(0.0215)
$\ln ASSET_0$			-0.3033 ***	-0.0333 ***
			(0.0756)	(0.0083)
$\overline{PCM}$			1.2541	0.1378
			(0.9885)	(0.1086)
$\overline{LIQR}$			0.2618	0.0288
			(0.2675)	(0.0294)
$\overline{\ln ASSET}$			0.4569 ***	0.0502 ***
			(0.0935)	(0.0103)
Cons.	-6.6478 ***		-4.2608 ***	
	(0.442)		(0.8400)	
$\ln \sigma_u^2 \ / \ \sigma_\alpha^2$	2.3152 ***		0.0727	
	(0.0601)		(0.7111)	
σ_u	3.1822 ***			
	(0.0956)			
ρ	0.9101 ***			
	(0.0049)			

Values in parenthesis are the standard errors. Asterisks *, ** and *** indicate significant at 10%, 5% and 1% level, respectively. The coefficients of time dummy variables are omitted for space.

Table 5 Probability of exporting

	(1) Total machinery-manufacturing	(2) General machinery	(3) Electrical machinery	(4) Transportation equipment
Observed	0.455	0.568	0.393	0.385
Estimated	0.366	0.620	0.242	0.137

Table 6 Raw and estimated probabilities

	(1) Total machinery-manufacturing	(2) General machinery	(3) Electrical machinery	(4) Transportation equipment
	Raw probability			
Entry prob.	0.050	0.066	0.043	0.042
Exit prob.	0.046	0.040	0.054	0.047
Observed hysteresis	0.904	0.894	0.903	0.911
Export prob.	0.517	0.619	0.441	0.472
Mean duration	21.508	24.709	18.412	21.086
	Estimated probability with unobserved firm-specific factor			
Entry prob.	0.232	0.267	0.207	0.203
Exit prob.	0.267	0.215	0.291	0.296
Genuine hysteresis	0.501	0.518	0.502	0.501
Export prob.	0.465	0.553	0.416	0.407
Mean duration	3.743	4.644	3.441	3.382
	Estimated probability without unobserved firm-specific factor			
Entry prob.	0.124	0.176	0.107	0.072
Exit prob.	0.155	0.096	0.166	0.231
Genuine hysteresis	0.721	0.728	0.727	0.697
Export prob.	0.445	0.647	0.391	0.238
Mean duration	6.467	10.422	6.012	4.332

Table A1 Number of firms of machinery-manufacturing in the survey by sub industry

	(1) Total machinery-manufacturing	(2) General machinery	(3) Electrical machinery	(4) Transportation equipment
1994	4,972	1,914	1,960	1,098
1995	5,048	1,903	1,991	1,154
1996	5,310	2,005	2,104	1,201
1997	5,338	2,036	2,113	1,189
1998	5,317	2,037	2,092	1,188
1999	5,285	2,017	2,069	1,199
2000	5,223	1,991	2,049	1,183
2001	5,133	1,980	2,032	1,121
2002	5,129	2,016	1,996	1,117
2003	5,082	1,993	1,981	1,108
2004	4,914	1,925	1,901	1,088
2005	5,214	2,016	2,040	1,158
2006	5,132	1,991	1,986	1,155
2007	5,075	1,960	1,937	1,178
2008	5,315	2,019	2,027	1,269
2009	5,252	2,042	1,954	1,256
2010	5,084	1,964	1,887	1,233
2011	5,098	2,008	1,832	1,258
2012	5,132	2,025	1,837	1,270
2013	5,057	2,022	1,770	1,265
2014	4,993	2,010	1,699	1,284
2015	4,941	1,977	1,654	1,310
Total	113,037	43,917	42,602	26,518

Data source: the Basic Survey of Japanese Business Structure and Activities

Table A2 Number of firms in machinery-manufacturing sector by industry

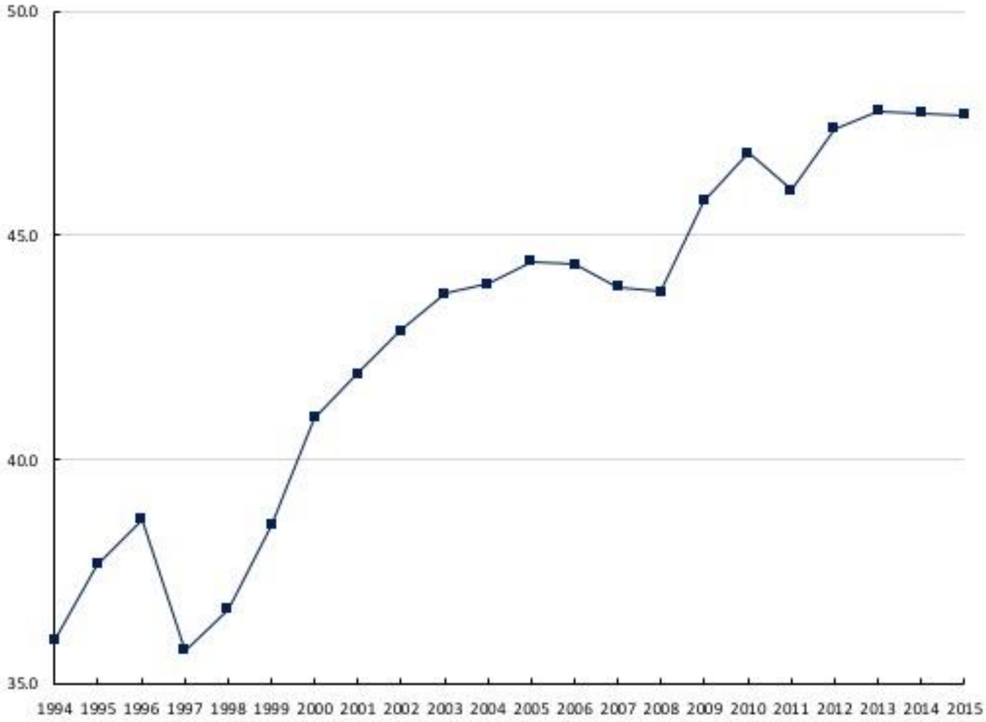
	(1) Total machinery-manufacturing	(2) General machinery	(3) Electrical machinery	(4) Transportation equipment
1994	1,521	560	596	365
1995	1,694	623	672	399
1996	1,757	647	697	413
1997	1,827	675	727	425
1998	1,887	707	741	439
1999	1,936	719	770	447
2000	1,996	733	808	455
2001	2,071	788	824	459
2002	2,136	804	857	475
2003	2,185	821	872	492
2004	2,225	844	872	509
2005	2,234	827	881	526
2006	2,239	825	876	538
2007	2,172	777	865	530
2008	2,101	769	825	507
2009	2,048	744	802	502
2010	1,984	730	767	487
2011	1,939	724	738	477
2012	1,872	706	700	466
2013	1,813	690	667	456
2014	1,749	676	625	448
2015	1,676	640	594	442
Total	43,062	16,029	16,776	10,257

Data source: the Basic Survey of Japanese Business Structure and Activities

Table A3 Descriptive statistics of explanatory variables

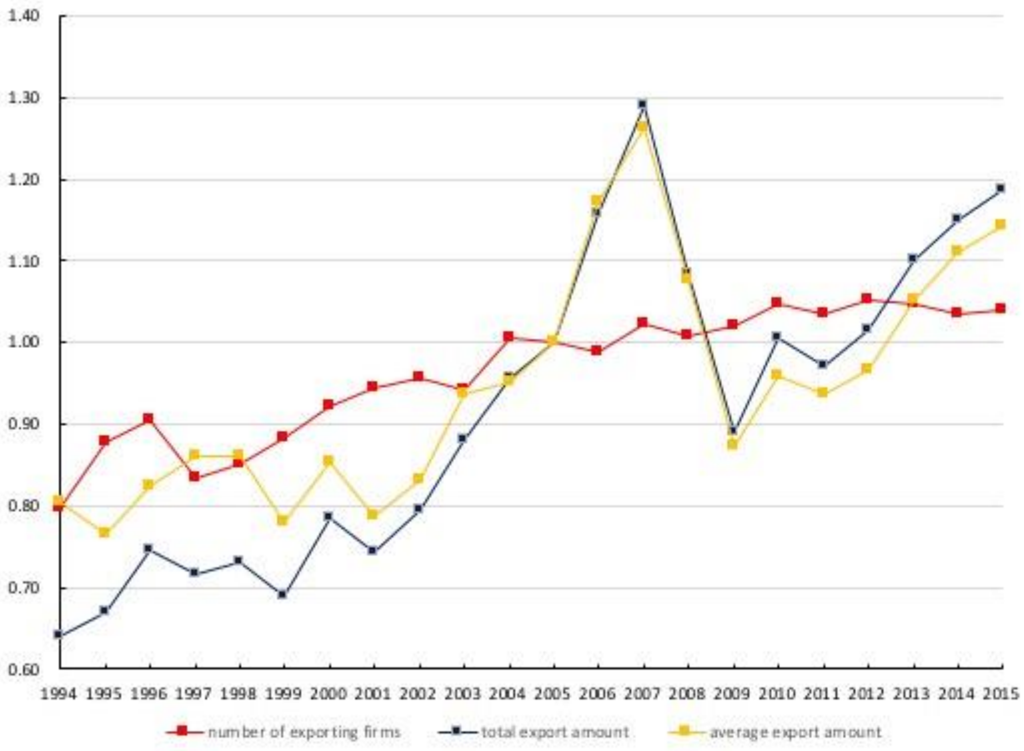
	(1) Total machinery-manufacturing	(2) General machinery	(3) Electrical machinery	(4) Transportation equipment
number of observations	43,062	16,284	16,542	10,236
		PCM: price cost margin		
mean	1.036	1.045	1.032	1.028
standard deviation	0.061	0.071	0.060	0.041
min	0.595	0.595	0.607	0.759
1st quartile	1.007	1.011	1.005	1.007
median	1.028	1.037	1.025	1.024
3rd quartile	1.061	1.077	1.056	1.047
max	1.483	1.483	1.403	1.299
		LIQ: Liquidity ratio		
mean	0.171	0.230	0.168	0.084
standard deviation	0.225	0.204	0.241	0.199
min	-1.362	-0.741	-1.362	-0.757
1st quartile	0.030	0.097	0.029	-0.041
median	0.176	0.233	0.179	0.082
3rd quartile	0.326	0.374	0.332	0.215
max	0.793	0.792	0.793	0.734
		ln*ASSET*: logarithm of total asset		
mean	8.329	8.327	8.078	8.378
standard deviation	1.417	1.230	1.475	1.504
min	4.344	5.565	4.344	5.498
1st quartile	7.353	7.474	7.051	7.667
median	8.085	8.068	7.843	8.464
3rd quartile	9.095	8.969	8.913	9.597
max	14.355	13.298	14.071	14.355

Data source: the Basic Survey of Japanese Business Structure and Activities



Data source: the Basic Survey of Japanese Business Structure and Activities

Figure 1 Proportion of exporting firms in machinery-manufacturing industry (%)



Data source: the Basic Survey of Japanese Business Structure and Activities

Figure 2 Number of exporting firms, export amount and average export amount (2005=1.0)

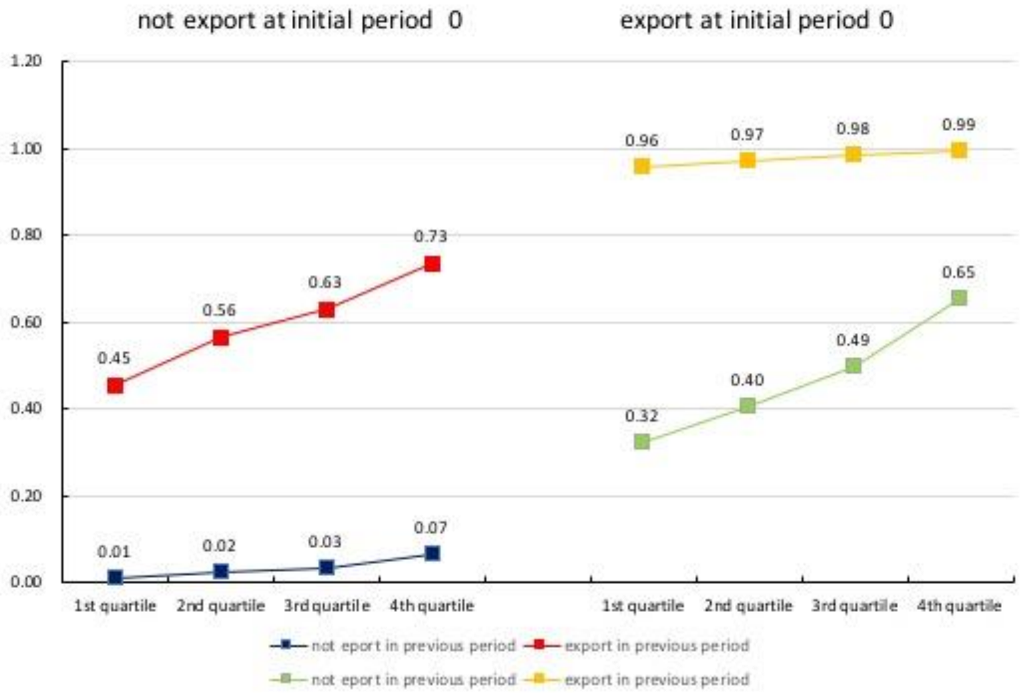


Figure 3. Persistence and entry probability by unobserved heterogeneity c_i