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Macroeconomic Shocks and Firms' Overseas Expansion: Evidence from the Factor-Augmented VAR Approach

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Macroeconomic Shocks and Firms' Overseas Expansion:

Evidence from the Factor-Augmented VAR Approach*

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Abstract

This paper analyzes the effects of macroeconomic variations, such as exchange rate and global GDP, on Japanese firms' overseas expansion behaviors. Particularly, we examine how macroeconomic shocks affect the number of overseas subsidiaries of individual firms under the framework of the factor-augmented VAR (FAVAR) model. Moreover, we combine the Tobit and FAVAR models to incorporate firms that own no overseas subsidiaries into our empirical analysis. The results can be summarized as follows. First, we show that most firms increase overseas subsidiaries in response to the appreciation of the exchange rate. However, the results of forecast error variance decomposition show that, compared with the exchange rate, global GDP shocks play a more important role in the variation of Japanese firms' overseas expansion. Additionally, our results indicate that the variation of the exchange rate has only a temporary effect on overseas expansion behaviors.

Keywords: exchange rate, overseas affiliate, factor-augmented VAR model, Tobit model

JEL classification: F31, F44, C32

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1. Introduction

The causality between the variation of the exchange rate and foreign direct investment (FDI) flows has been verified by many existing studies. A large stream of empirical studies focused on the first and second moments of the exchange rate, that is, how the depreciation or devaluation of the host country's currency is associated with FDI inflows into the country or how exchange rate volatility would affect FDI inflows.

Several studies have empirically examined the effects of the exchange rate on FDI (Froot and Stein 1991; Klein and Rosengren 1994; Blonigen 1997; Bayoumi and Lipworth 1998; Goldberg and Klein 1998; Ito 2000; Sazanami and Wong 1997; Sazanami et al. 2003; Kiyota and Urata 2004). However, among the few studies that focused on the impacts of exchange rate volatility, the findings are mixed. For instance, Cushman (1985 and 1988) and Goldberg and Kolstad (1995) find a positive impact of exchange rate volatility on FDI, while Urata and Kawai (2000) and Bénassy-Quéré et al. (2001) find a negative impact.

There are at least two reasons for the mixed results concerning the impacts of exchange rate volatility on FDI. One reason is the aggregation problem, as suggested by Kiyota and Urata (2004).[4] Most previous studies use aggregated national- or industry-level data without further breakdowns. However, as shown by Froot and Stein (1991) and Sazanami et al. (2003), the analysis of national-level data may result in ambiguous results because exchange rate volatilities among industries may offset one another. Similarly, industry-level data may also be too aggregated. As Melitz and Redding (2014) indicate, there is only a limited number of firms within an industry or area that choose to be

[4] Kiyota and Urata (2004) use industry-level outward FDI data on Japan for analysis.

engaged in FDI. Therefore, the aggregated index cannot differentiate the heterogeneity of FDI firms from that of non-FDI firms. To better capture the impact of the exchange rate on firms' decision making for overseas investments, we combine firm-level data from the Toyo Keizai's Overseas Japanese companies' database with financial information from Nikkei Needs Financial Quest, while also controlling for other macroeconomic factors.

[Figure 1 inserted here]

Further, we use the number of foreign affiliates owned by individual Japanese firms as a proxy for FDI.[5] From Figure 1, the relationship between the number of Japanese firms' overseas affiliates and real effective exchange rate (REER) seems positive. Although firm-level data can help overcome the heterogeneity issue, when we use these data, all firms in the sample will be faced with the same exchange rate at a certain time point. This approach will complicate our identification because the impact of the exchange rate on FDI will be contaminated by other macroeconomic factors. Using firms' historical export/import data, previous studies attempt to derive the ease with which firms can react to exchange rate variations and then control for it as a proxy of firm heterogeneity so that the impact of the exchange rate can be singled out (e.g., Klein et al. 2003; Moser et al. 2010; Nucci and Pozzolo 2010).

Analogous to these studies, we apply the FAVAR model proposed by Bernanke et al. (2005). Specifically, we extract one unobserved factor from the number of overseas affiliates of each manufacturing firm and then estimate the VAR model that builds on this

[5] It has been argued that the revenue-weighted index of each overseas affiliate would be a more reasonable proxy; however, we do not have access to the information of affiliates. We will consider analyzing this issue in future studies.

single factor and additional macroeconomic variables. By applying this method, we can clarify the dynamic relationship between the factor and macro variables, as well as that between the factor and the number of an individual firm's overseas affiliates. Furthermore, unlike the previous studies on the static relationship between exchange rate volatility and one-time FDI, this paper attempts to capture the dynamic variations in the number of overseas affiliates after macroeconomic shocks occur, through the lens of the VAR model. One practical caveat is that, when we focus on the number of overseas affiliates, the firms that have no affiliates will be dropped from the sample. To deal with this truncation problem, we use the Tobit model nested within the FAVAR setting. In other words, for firms that have zero overseas affiliates, we assume that firms that have potentially negative number of affiliates also exist (and are unobservable), and estimate this potential number. To the best of our best knowledge, this study is a pioneer in exploring the impact of macroeconomic variation on individual firms' outward FDI decisions, while also extending the conventional FAVAR model by its combination with the Tobit model.

The findings can be summarized as follows. First, the appreciation of the exchange rate leads to an increasing number of overseas affiliates of the firms. However, the impact of the exchange rate on FDI is temporary. Second, after we control for other macroeconomic factors, we show that the world GDP has a more long-lasting and profound influence on firms' decision for outward FDI.

In view of the above, this study is related to two literature streams. The first one lies in the context of labor economics, specifically, the question of whether the hollowing out phenomenon did arise in Japan and to what extent we can relate it to the appreciation of Japanese currency. The second one derives from macroeconomic modeling and shows how firms' decision making evolves over time under the impact of exchange rate volatility.

The former literature stream focuses on economic intuition, whereas the latter tends to approach the issue from a more technical perspective. However, both point in the same direction regarding the impact of the exchange rate variation. Therefore, clarifying this theoretical puzzle will have significant policy implications for other nations as well.

The remainder of the paper is organized as follows. The next section introduces the background of why we use FAVAR model. Section 3 presents the estimation strategy and data used for this study. Section 4 shows the results and Section 5 concludes the paper.

2. Background of applying the FAVAR model

The FAVAR model was originally proposed by Bernanke et al. (2005) to cope with the problem of sparse information sets in typical VAR analyses. Building on the dynamic factor model, developed by Stock and Watson (2002), the relatively small set of factors extracted from the large dataset, and the variables of interest (e.g., the Federal Fund rate) composes the system of the FAVAR model, so that it is free from the degrees-of-freedom limitation despite including large amounts of information. Bernanke et al. (2005) document three advantages of using the FAVAR model with a large series dataset. First, the FAVAR model reflects the information possessed by economic agents better than the standard VAR model and thus mitigates the possibility of contaminating policy innovations. Second, it excludes arbitrariness, which occurs for the choice of a time series, including in the VAR system. Finally, we can examine the responses of a number of variables in the system to structural innovations at the same time, which cannot be done in the standard VAR model because the inclusion of variables is limited by the degrees of freedom.

Our analysis mainly relies on the third point. As noted above, the FAVAR model allows us to identify the influence of macroeconomic shocks, such as the variations in the exchange rate and the business cycle worldwide, on the behaviors of numerous firms comprehensively and simultaneously. Therefore, we apply the FAVAR model in our analysis.

3. Methodology and data

3-1. Factor-Augmented VAR model with censored variable

The details of the empirical strategy are as follows. First, we define F_t as an $m \times 1$ vector that represents unobserved factors.[6] $X_t^* = \left(x_{1t}^*, \cdots, x_{n(t)t}^*\right)'$ is an $n(t) \times 1$ vector of the latent number of firm i's overseas affiliates in year t, denoted by x_{it}^*. As shown in equation (1), we assume F_t has a dynamic impact on X_t^*. Because some firms might go bankrupt at some time point during the analysis period, these observations will be dropped from the sample, meaning we can only estimate $n(t)$ based on unbalanced panel data.

$$X_t^* = \Lambda F_t + z_{t-1}'\beta + e_t,\ e_t \sim N(0, R). \tag{1}$$

In equation (1), z_{t-1} is an $l \times n(t)$ vector that includes the observed exogenous variables that might affect X_t^* other than F_t. R is a matrix with the diagonal elements $e_t = \left(e_{1t}, \cdots, e_{n(t)t}\right)'$. Λ is called factor loading and represents an $n(t) \times m$ vector that shows the relationship between extracted factors and the number of each firm's overseas affiliates. Furthermore, as indicated in equation (2), we define $x_{it}\ as\ x_{it}^*$ if the threshold

[6] Throughout the text, we alternatively use "factor shock" to indicate F_t.

value is above 0 and $x_{it} = 0$ otherwise. In practice, a Tobit model can better capture this mechanism.

$$x_{it} = \begin{cases} x_{it}^* \text{ if } x_{it}^* > 0 \\ 0 \text{ if } x_{it}^* \leq 0 \end{cases}. \tag{2}$$

Next, we define Y_t as a $k \times 1$ vector that includes the observed macroeconomic variables. The dynamics between F_t and Y_t can be described using the following VAR model:

$$\begin{bmatrix} F_t \\ Y_t \end{bmatrix} = \Phi \begin{bmatrix} F_{t-1} \\ Y_{t-1} \end{bmatrix} + u_t, \qquad u_t \sim N(0, Q). \tag{3}$$

In equation (3), Φ is the coefficient matrix, whereas Q represents the variance-covariance matrix of error term u_t. To clarify how exogenous factors affect firms' overseas investment behavior, we define Y_t as a 2×1 vector that includes world GDP and REER at time *t*. In contrast to the conventional VAR model that only includes observable endogenous variables Y_t, the current specification adds unobserved F_t to the estimation system, and we call equation (3) the factor-augmented VAR model.

We conduct the analysis outlined above using firm-level micro data. Since we can identify the channel through which Y_t affects F_t and the relationship between F_t and x_{it}^* is captured by Λ, we can then derive to what extent the shock in Y_t affects x_{it}^*. By doing so, we can quantify individual firms' reactions to the macroeconomic shock, especially in terms of the exchange rate.

3-2. MCMC estimation

The FAVAR model mentioned above is estimated by the Bayesian Markov Chain Monte Carlo (MCMC) method via the Gibbs sampler. To do so, we construct the state-space model, where equation (3) is regarded as the state-equation and equation (1)', which is the transformation of (1), as the observation equation:

$$\begin{bmatrix} X_t^* \\ Y_t \end{bmatrix} = \begin{bmatrix} \Lambda & 0 \\ 0 & I_k \end{bmatrix} \begin{bmatrix} F_t \\ Y_t \end{bmatrix} + \begin{bmatrix} z_{t-1}' \\ 0_{k\times l} \end{bmatrix} \beta + \begin{bmatrix} e_t \\ 0 \end{bmatrix}. \qquad (1)'$$

In this system, Y_t is also treated as the latent variable, as well as F_t. Since our model comprises several parameters and the latent variables denoted by Θ, where $\Theta = \Lambda, \beta, \Phi, R, Q, \{F_t\}_{t=1}^T, \{X_t^*\}_{t=1}^T$, the posterior distribution is too complicated to calculate analytically and, thus, the MCMC method is suitable for estimation. Given observed data $y = \{Y_t\}_{t=1}^T, \{z_t\}_{t=1}^T$ and prior density functions $\pi(\Theta)$, the samples from the posterior distribution $\pi(\Theta \mid y)$ are obtained as follows:

1. Set initial values of $\Lambda^{(0)}$, $\beta^{(0)}$, $\Phi^{(0)}$, $R^{(0)}$, $Q^{(0)}$, ${\{F_t\}_{t=1}^T}^{(0)}$, ${\{X_t^*\}_{t=1}^T}^{(0)}$, and $j = 1$.
2. Draw ${\{F_t\}_{t=1}^T}^{(j)}$ from $\pi\left(\{F_t\}_{t=1}^T \mid \Lambda^{(j-1)}, \beta^{(j-1)}, \Phi^{(j-1)}, R^{(j-1)}, Q^{(j-1)}, {\{X_t^*\}_{t=1}^T}^{(j-1)}, y\right)$.
3. Draw $\Lambda^{(j)}$ and $\beta^{(j)}$ from $\pi\left(\Lambda, \beta \,\middle|\, {\{F_t\}_{t=1}^T}^{(j)}, {\{X_t^*\}_{t=1}^T}^{(j-1)}, R^{(j-1)}, y\right)$.
4. Draw $R^{(j)}$ from $\pi\left(R \mid {\{F_t\}_{t=1}^T}^{(j)}, {\{X_t^*\}_{t=1}^T}^{(j-1)}, \Lambda^{(j)}, \beta^{(j)}, y\right)$.
5. Draw ${x_{it}^*}^{(j)}$ in ${\{X_t^*\}_{t=1}^T}^{(j)}$ from $\pi\left(x_{it}^* \mid {\{F_t\}_{t=1}^T}^{(j)}, \Lambda^{(j)}, \beta^{(j)}, R^{(j)}, \{z_t\}_{t=1}^T\right)$ truncated between $-\infty$ and 0.

6. Draw $\Phi^{(j)}$ from $\pi\left(\Phi \mid \{F_t\}_{t=1}^{T}{}^{(j)}, Q^{(j-1)}, y\right)$.

7. Draw $Q^{(j)}$ from $\pi\left(Q \mid \{F_t\}_{t=1}^{T}{}^{(j)}, \Phi^{(j)}, y\right)$.

8. Return to step 2 until N iterations have been completed.

For the above process, N is set at 25,000, but the initial 5,000 samples are discarded as burn-in. In the following, we briefly explain the process of sampling for each step. In step 2, we employ the Kalman filter and Kalman smoother to our state-space specification to sample the latent factor $\{F_t\}_{t=1}^{T}$. To draw Λ and β simultaneously in step 3, equation (1) is transformed as:

$$X_t^* = [F_t \times I_n \quad z_{t-1}'] \begin{bmatrix} \Lambda \\ \beta \end{bmatrix} + e_t.$$

Specifically, the equation can be expressed as:

$$\begin{bmatrix} x_{1t}^* \\ x_{2t}^* \\ \vdots \\ x_{nt}^* \end{bmatrix} = \begin{bmatrix} F_t & 0 & \cdots & 0 & z_{1,t-1}^1 & \cdots & z_{1,t-1}^l \\ 0 & F_t & \ddots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \cdots & \ddots & 0 & \vdots & \vdots & \vdots \\ 0 & \cdots & 0 & F_t & z_{n,t-1}^1 & \cdots & z_{n,t-1}^l \end{bmatrix} \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \vdots \\ \lambda_n \\ \beta_1 \\ \vdots \\ \beta_l \end{bmatrix} + e_t.$$

As mentioned above, our model is estimated using the Bayesian method, so that λ_1 is normalized to be 1 to identify the latent factor uniquely.[7] Thus, the system for estimation in this study is given by

[7] This restriction for identifying the latent factor is adopted by Bernanke et al. (2005) and Belviso and Milani (2006).

$$\begin{bmatrix} x_{1t}^* - F_t \\ x_{2t}^* \\ \vdots \\ x_{nt}^* \end{bmatrix} = \begin{bmatrix} 0 & \cdots & 0 & z_{1,t-1}^1 & \cdots & z_{1,t-1}^l \\ F_t & \ddots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \ddots & 0 & \vdots & \vdots & \vdots \\ 0 & \cdots & F_t & z_{n,t-1}^1 & \cdots & z_{n,t-1}^l \end{bmatrix} \begin{bmatrix} \lambda_2 \\ \vdots \\ \lambda_n \\ \beta_1 \\ \vdots \\ \beta_l \end{bmatrix} + e_t.$$

Here, let us denote $\tilde{\Lambda} = [\lambda_2, \cdots, \lambda_n, \beta_1, \cdots, \beta_l]'$ and

$$\tilde{F}_t = \begin{bmatrix} 0 & \cdots & 0 & z_{1,t-1}^1 & \cdots & z_{1,t-1}^l \\ F_t & \ddots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \ddots & 0 & \vdots & \vdots & \vdots \\ 0 & \cdots & F_t & z_{n,t-1}^1 & \cdots & z_{n,t-1}^l \end{bmatrix},$$

and then assume $\tilde{\Lambda} \sim N(h_0, H_0)$ for the prior of $\tilde{\Lambda}$. The posterior distribution of $\tilde{\Lambda}$ is obtained as:

$$\tilde{\Lambda} \mid \{F_t\}_{t=1}^T, \{X_t^*\}_{t=1}^T, R, \{z_t\}_{t=1}^T \sim N(h_1, H_1),$$

where $h_1 = H_1\left(H_0^{-1} h_0 + \sum_{t=1}^T \tilde{F}_t' R^{-1} X_t^*\right)$ and $H_1^{-1} = H_0^{-1} + \sum_{t=1}^T \tilde{F}_t' R^{-1} \tilde{F}_t$. In step 4, under the prior distribution of $R_{ii}^{-1} \sim Gamma\left(\frac{w_0}{2}, \frac{w_0 S_0}{2}\right)$, where R_{ii} is the (i, i) element of R, the random sample of R_{ii}^{-1} is drawn from

$$R_{ii}^{-1} \mid \{F_t\}_{t=1}^T, \{X_t^*\}_{t=1}^T, \Lambda, \{z_t\}_{t=1}^T$$
$$\sim Gamma\left(\frac{w_1}{2}, \frac{w_1 S_1}{2}\right),$$

where $w_1 = w_0 + T$, $w_1 S_1 = w_0 S_0 + \sum_{t=1}^{T} e_{it}^2$, and $e_{it} = x_{it}^* - \tilde{F}_{it}\widetilde{\Lambda}$.

Since x_{it}^* follows a normal distribution of mean $\lambda_i F_t + z'_{i,t-1}\beta$ and variance R_{ii}, as shown in equation (1), for the observations that are $x_{it} = 0$, latent variable x_{it}^* is generated from:

$$x_{it}^* \sim TN_{(-\infty,0]}\left(\lambda_i F_t + z'_{i,t-1}\beta, R_{ii}\right).$$

As for Φ and Q in steps 6 and 7, we regard the sampling result of $\{F_t\}_{t=1}^{T}$ as data and set the normal distribution and Wishart distribution for the prior of Φ and Q^{-1} as follows:

$$\Phi \sim N(b_0, B_0), \qquad Q^{-1} \sim W(v_0, V_0).$$

Then, the conditional posterior density functions for Φ and Q^{-1} are, respectively:

$$\Phi \mid \{F_t\}_{t=1}^{T}, \{Y_t\}_{t=1}^{T}, Q \sim N(b_1, B_1),$$
$$Q^{-1} \sim W(v_1, V_1).$$

Here, $b_1 = B_1\left(B_0^{-1} b_0 + \sum_{t=2}^{T} \hat{F}_{t-1} Q^{-1} \hat{F}_t\right)$, $B_1^{-1} = B_0^{-1} + \sum_{t=2}^{T} \hat{F}_{t-1} Q^{-1} \hat{F}_{t-1}$, $v_1 = v_0 + T - 1$, and $V_1^{-1} = V_0^{-1} + \sum_{t=2}^{T}\left(\hat{F}_t - \Phi\hat{F}_{t-1}\right)\left(\hat{F}_t - \Phi\hat{F}_{t-1}\right)'$, where $\hat{F}_t = [F_t, Y_t]'$.

3-3. Data

Firm-level FDI data (1999–2014)[8] are taken from Toyo Keizai's Kaigai Sinshutsu

[8] Since the one=period lag is included in the VAR model, the data used in practice range from 2000 to 2014.

Kigyo Soran, consisting of green-field and acquisition (20% or higher equity acquisitions) investments. We focus on manufacturing firms listed on either the first or the second section of the Tokyo Stock Exchange. We also limit our estimation to firms that have observations for at least eight years. In other words, we omit firms that have too many missing values or do not have enough observations because of bankruptcy during the estimation period. Finally, 715 firms were used for analysis.

First, we extract the unobserved factors based on the variation of these firms' overseas affiliates. Second, as for explanatory variables z_{t-1} in equation (1), overseas export revenue/total revenue, R&D expenditure/total revenue, capital investment/total revenue, and liabilities/assets are used. These data are all obtained from Nikkei's Needs Financial Quest. The information on REER is taken from the homepage of the Bank of Japan, whereas the world GDP comes from Constant GDP per capita for the World, constructed by Federal Reserve Bank of St. Louis.

It is worth noticing the identification of VAR model. The number of overseas affiliates in year t is based on the value in October, REER is the average value from January to December, and world GDP is the flow value aggregated from January to December. Because of the deviation in the timing of observations, the order of the variables used in the VAR model of equation (3) is as follows: factors, world GDP, and REER. By applying the recursive formulation of the Cholesky factorization, we can identify the structural shock.[9]

Concerning the specification of the VAR model, the lag length of our system is set as one year, and all variables are included at this level. Furthermore, in equation (1), we control for firm-level fixed effects and, in equation (3), we add the constant term. Because

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[9] The financial data are all based on observations during the accounting period in March.

the estimated coefficients will be interpreted as elasticity, it is reasonable for the variables to take logarithm values. While this will work for REER and world GDP, since the number of overseas affiliates have zero values, which makes it impossible to take the logarithm, we apply the inverse hyperbolic sine transformation to solve the problem.[10]

Finally, for the prior distribution of parameters, we assume that $\widetilde{\Lambda} = [\Lambda' \ \beta']'$ and Φ follow the normal distribution, the inverse of R_{ii} follows the Gamma distribution, and the inverse matrix of Q is subject to the Wishart distribution.

$$
\begin{aligned}
\widetilde{\Lambda} &\sim N(0, I), \\
\Phi &\sim N(0, I), \\
R_{ii}^{-1} &\sim Gamma\left(\frac{40}{2}, \frac{40 \times (0.001)^2}{2}\right), \\
Q^{-1} &\sim W(100, I \times 100).
\end{aligned}
\tag{4}
$$

4. Estimation results

4-1. Factor's impulse response function and variance decomposition

Figure 2 shows the impulse response function of the factors (for the number of overseas affiliates) with respect to the world GDP (a) and the exchange rate (b). The impulse responses to a one standard deviation macroeconomic shocks are included—the blue solid line indicates the median response based on all sampled responses, whereas the red dotted line indicates the 68% confidence intervals.

[Figure 2 inserted here]

[10] The inverse hyperbolic sine transformation of a certain x is defined as $\ln\left(x + (x^2 + 1)^{1/2}\right)$.

From the results, the world GDP has a positive impact on the factors of overseas affiliates and it is significant for 68% confidence intervals. In the meantime, the responses to the exchange rate shock are confirmed not to be significant. By the median response, the factors of the overseas affiliates show a continuous response to the world GDP shock, whereas the response to the exchange rate converges to zero.

Furthermore, to confirm the scale of each shock's influence on the factors, we use Table 1 to summarize the results of the variance decomposition by shocks. Variance decomposition is the methodology that quantifies the impact of each macroeconomic shock on the unpredictable volatility of the variables included in the VAR system. Table 1 shows the relative contributions of each shock on the factor one, two, and five years ahead, respectively, in terms of the average square of the error term. Since this study conducts a Bayesian estimation based on the MCMC method, we calculate the variance decomposition for each group of sampling observations and show the average value, together with the 68% confidence intervals.

［Table 1 inserted here］

From Table 1, the variation of the number of overseas affiliates can be mostly explained by the factor shock. This is due to the fact that we adopt the recursive constraint based on the Cholesky decomposition. In other words, because the factor shock under the recursive constraint is the only one that affects the change in the number of overseas affiliates when the shock occurs, its impact is larger than that of the other shocks. One thing that worth noticing is that, in the second and third columns, the world GDP shock has a larger long-term impact on the dependent variable than the exchange rate does. In comparison to the exchange rate, the impact of the world GDP shock is twice after five years and three times after 10 years. In this way, for the determinants of individual firms' overseas investment rather than exchange rate, the world GDP plays an even more important role. This is in accordance with the results of the impulse response shown in Figure 2.

4-2. Response to the number of overseas affiliates

Hitherto, we have verified the impacts of world GDP and exchange rate on the decision making for overseas investment of Japanese firms in general. To take a step further, we can calculate Λ in equation (1) and thus identify the macroeconomic shocks' impact on each individual firm. That is, using the FAVAR model, it is possible to systematically estimate the impact on the 715 firms by respectively combining equations (1)' and (3). However, due to space constraints, we only show the histogram based on 715 firms' impulse response function in Figure 3.

［Figure 3 inserted here］

Figures 3(a) and 3(b) are the histograms of the impulse response functions for world GDP and exchange rate, respectively. The horizontal axis shows the response, while the vertical one indicates the ratio of firms within each interval. In Figure 3(a), the interval is 0.1, whereas it is 0.02 in Figure 3(b). The histograms are based on the median value of each firm's response. The blue solid line indicates the distribution of the responses one year after the shock. The red and green dotted lines are for five and 10 years, respectively.

First, in Figure 3(a), the blue line shows that the peak of the histogram is near zero and nearly half of firms do not have any responses. However, after five years, the firms that increase and decrease overseas affiliates diverge. Furthermore, the shapes of the responses after five and 10 years are similar, which means that the influence of the shock is durable. In Figure 2(a), the factor of the overseas affiliates shows a positive response to the world GDP shock. However, when we look at individual firms' responses, the histogram skews to the left, which means that there are more firms that decrease their number of overseas affiliates after a positive world GDP shock. The result is opposite to our intuition, and to better understand the mechanism behind it, we assume it is necessary to divide the samples and conduct more detailed analyses.[11]

On the other hand, one year after the exchange rate shock, the distribution tail of the responses becomes wider, which means that firms react in a relatively early stage once they are affected by the shock. While in the short run, more than half of the firms increase their overseas affiliates in response to an increase in exchange rate, after 10 years, the peak of the histogram is near zero, showing that the impact of the exchange rate shock on firms' overseas investment decisions might be temporary.

5. Conclusions

This study analyzes the dynamic relationship between macroeconomic shocks such as exchange rate and individual firms' overseas investment decision in terms of the number overseas affiliates. Specifically, we extract one unobserved factor from the

[11] For example, when the economic situation improves in developing countries, firms will shut down several foreign affiliates in advanced countries and open new affiliates in those developing nations. In this paper, such a behavior is regarded as decreasing overseas affiliates, so that it is necessary to divide the sample by region and conduct further analyses in future studies.

number of overseas affiliates of each manufacturing firm and then estimate a VAR model that builds on this single factor and macroeconomic variables. Specifically, we embed a Tobit model in the FAVAR context and apply firm-level micro data while controlling for year fixed effects. By using a VAR model for time series analysis, we can capture not only the static relationship between macroeconomic variables and firm behavior, but also how economic shocks dynamically affect firms' responses. This is the major contribution of this study.

By analyzing impulse response and variance decomposition based on the factors extracted from the number of Japanese firms' overseas affiliates, we verify that both the exchange rate and world GDP variation affect firms' decisions of investing abroad. When there is an increase in the exchange rate, most firms will increase their number of overseas affiliates; however, the impact of the world's GDP is even larger. Additionally, in contrast to the fact that the impact of the exchange rate on firms' overseas investment is temporary, the world GDP has a continuous influence on firms' decisions in terms of their outward FDI. By far, many studies have focused on the determinants of inward FDI, because FDI is an important channel through which a host country can improve its technology, as well as the resource allocation efficiency. By contrast, in this paper, we attempt to lay the micro-level foundation for quantifying the influence that macroeconomic factors have on individual firms' outward FDI. The new insights from the supply side will have tremendous policy implications for future study.

However, the current study has its limitations. As outlined in the previous section, the result on the influence that world GDP has on firms' reactions is opposite to our expectations, which needs further justification. We might divide the destinations by different patterns or regions. Furthermore, structural shocks, such as financial policy and risk premium, can also change the exchange rate; however, the current Cholesky factorization under recursive constraint does not consider these factors. To mitigate such problems, we will apply a similar FAVAR model with sign restrictions, as used by Ahmadi and Uhlig (2009). In this case, a theoretical model to describe the mechanism of firms' overseas investments will be proposed in future studies and more endogenous variables will be included in our VAR model.

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Figure 1: Correlation between the number of Japanese firms' overseas affiliates and the real effective exchange rate (authors' calculation based on the Basic Survey on Overseas Business Activities).

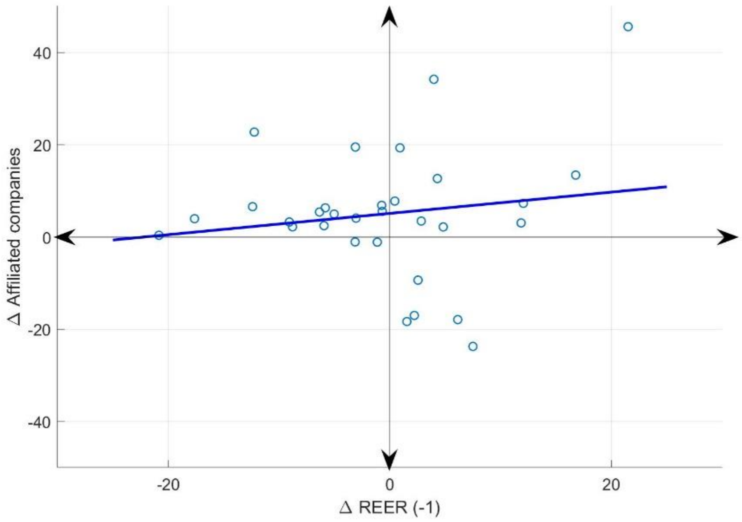
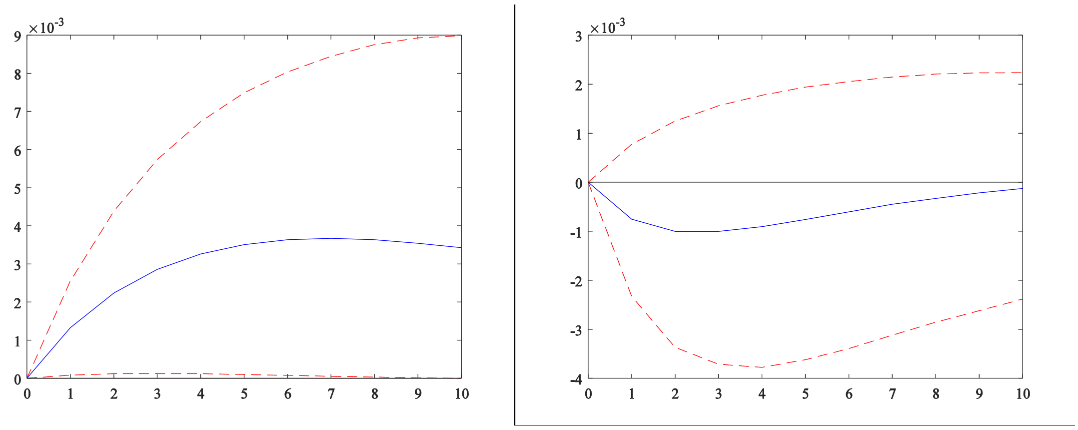


Figure 2: Impulse response function of factors with respect to world GDP and exchange rate shocks.

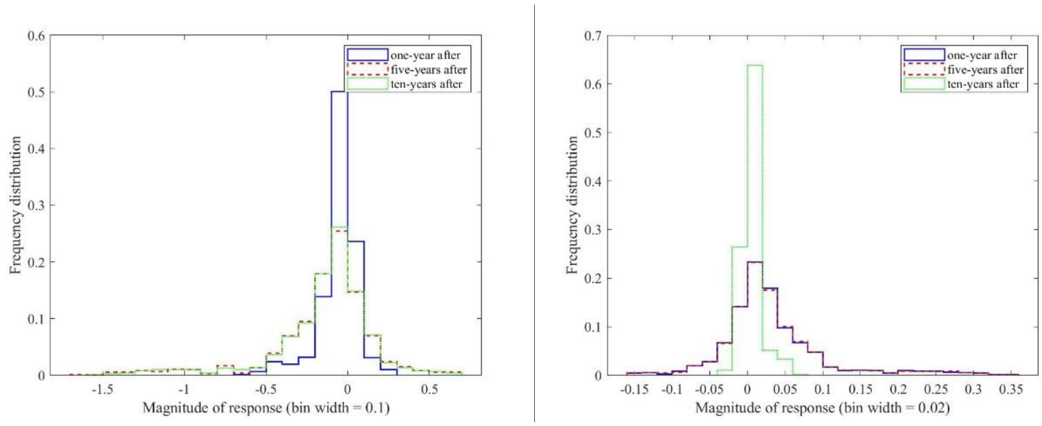
(a) World GDP shock (b) Exchange rate shock



Notes: Figures 2(a) and 2(b) show the responses of the overseas affiliate factor to world GDP and exchange rate shocks, respectively. The solid blue line indicates the average responses of the sample responses, whereas the red dotted line indicates 68% confidence intervals.

Figure 3: Individual firms' responses

(a) World GDP shock (b) Exchange rate shock



Notes: The horizontal axis shows the response, while vertical axis indicates the ratio of firms within each interval.

Table 1: Variance decomposition by shocks

	factor shock	world GDP shock	exchange rate shock
1 year later	98.6 [97.4, 99.8]	0.7 [0.0, 1.5]	0.7 [0.0, 1.3]
2 years later	96.5 [93.5, 99.4]	2.0 [0.1, 4.1]	1.5 [0.1, 3.0]
5 years later	89.7 [81.0, 98.1]	7.1 [0.4, 14.2]	3.2 [0.2, 6.5]
10 years later	81.0 [64.4, 96.5]	14.5 [0.8, 30.0]	4.4 [0.3, 8.8]

Notes: The values show the contribution each shock to the volatility of the dependent variable, while the values between parentheses indicate the 68% confidence intervals.

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