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Working Paper

The Impact of Exchange Rate on FDI and the Interdependence of FDI over Time

ADB Economics Working Paper Series, No. 164

Provided in Cooperation with:

Asian Development Bank (ADB), Manila

Suggested Citation: Alba, Joseph D.; Park, Donghyun; Wang, Peiming (2009) : The Impact of Exchange Rate on FDI and the Interdependence of FDI over Time, ADB Economics Working Paper Series, No. 164, Asian Development Bank (ADB), Manila, <https://hdl.handle.net/11540/1815>

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ADB Economics Working Paper Series



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No. 164 | June 2009



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Asian Development Bank

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1550 Metro Manila, Philippines
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©2008 by Asian Development Bank
June 2009
ISSN 1655-5252
Publication Stock No.

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Abstract

The paper examines the impact of exchange rates on foreign direct investment (FDI) inflows into the United States in the context of a model that allows for the interdependence of FDI over time. Interdependence is modeled as a two-state Markov process where the two states can be interpreted as either a favorable or an unfavorable environment for FDI in an industry. Unbalanced industry-level panel data from the US wholesale trade sector are used in the analysis and yield two main results. First, the paper finds evidence that FDI is interdependent over time. Second, under a favorable FDI environment, the exchange rate has a positive and significant effect on the average rate of FDI inflows.

I. Introduction

Foreign direct investment (FDI) flows into the United States (US) have shown substantial fluctuations in the 1980s and 1990s. A growing theoretical and empirical literature attempts to explain those fluctuations primarily in terms of the impact of the real exchange rate on FDI, including Froot and Stein (1991), Blonigen (1997), Klein and Rosengren (1994), Guo and Trivedi (2002) and Kiyota and Urata (2004). Theoretical considerations based on relative wealth effects and relative labor cost effects suggest that a stronger US dollar may deter FDI into the US.¹ At the same time, however, a stronger US dollar may improve the home-currency revenues and thus profitability of foreign firms entering the US market. This helps to explain the entry of foreign firms into the US market during the first half of the 1980s, when the US dollar appreciated sharply.

Interestingly, there was a tendency among foreign firms to remain in the US market when the US dollar returned to its original level. Such behavior is an example of hysteresis, or an effect that persists after its underlying cause has been removed. One possible explanation for the failure of foreign firms to exit the US market in the face of a falling dollar is the presence of sunk costs that cannot be recovered upon exit.² The exchange rate would have to fall below the entry-triggering level in order to trigger exit. Dixit (1989) further develops the concept of hysteresis by applying the theory of option pricing from financial economics to analyze investment under uncertainty.³ Dixit shows that greater price volatility leads to a wider range of prices in which inactive firms do not enter and active firms do not exit. That is, uncertainty expands the gap between the entry-triggering price and exit-triggering price, thereby deterring both entry and exit.

Campa (1993) develops an empirically testable model of FDI based on Dixit's model. Campa's model describes a risk-neutral foreign firm that has to incur a sunk cost in order to enter the US market. It has to decide, at each point in time, whether to enter the US market in this period or wait until the next period. The firm produces a good abroad and

¹ Froot and Stein (1991) point out that in the presence of capital market imperfections that make external finance more costly than internal finance, a real depreciation of the US dollar increases the relative wealth of foreign firms and gives them an advantage in buying US assets. Blonigen (1997) develops a theoretical model and finds empirical support for this viewpoint. Furthermore, Klein and Rosengren (1994) note that a weaker US dollar attracts foreign capital into the US by lowering the relative labor costs of the US.

² See Baldwin and Krugman (1989) and Baldwin (1989).

³ Pindyck (1991) provides an excellent review of the literature on investment decisions under uncertainty.

can sell it in the US market at a constant dollar price. Although the firm faces a certain price in US dollars, its returns in its home currency fluctuate if the bilateral exchange rate fluctuates. If the exchange rate is defined as units of foreign currency per US dollar, a higher exchange rate increases the home currency-profits. At the same time, the more volatile the exchange rate, the more volatile will be the home-currency returns, and the wider is the range of exchange rates in which neither entry nor exit occurs. Campa's model thus clearly predicts a positive effect of exchange rate and a negative effect of exchange rate volatility on FDI.⁴

Campa empirically tests his model using data consisting of a panel based on 61 four-digit Standard Industrial Classification (SIC) industries in the US wholesale trade sector for the period 1981–1987. The choice of wholesale industries eliminates the complications of manufacturing industries pertaining to input origin or final output destination.⁵ The dependent variable is the number of foreign firms that entered a US industry in a given year while the independent variables are measures of exchange rate level R , rate of change in the exchange rate μ , volatility of the exchange rate σ , sunk costs k , and variable costs of production in the US relative to foreign countries w .⁶ Our proxy for the last variable is unit labor costs in the US relative to foreign countries. Campa uses a Tobit model to estimate the probability that an FDI entry occurs in the US wholesale trade sector. The model predicts the probability of entry is positively related to R and μ , and negatively related to σ , k , and w . All variables other than μ have the predicted sign. Most importantly, the exchange rate level R has a significant positive effect and the standard deviation of the exchange rate σ has a significant negative effect.⁷

Tomlin (2000) extends Campa's sample period to 1993 and uses a zero-inflated Poisson (ZIP) model to analyze FDI in the US wholesale trade industry. While Campa calculates the probability that an FDI entry occurs, Tomlin estimates the average rate of FDI entries per industry for the period 1982 to 1993. Tomlin pools industry data for a period of 12-years, so that her model is in effect a cross-sectional model that does not consider interdependence over time. In contrast to Campa, Tomlin finds that neither the level nor the standard deviation of the exchange rate has any effect on the rate of FDI. This suggests that while exchange rate variables may affect the probability of entry, they do not affect the average rate of FDI entries.

All existing studies of FDI fail to consider the interdependence of FDI over time. This possibility was articulated by Caves (1971) using the concept of corporate rivalry in FDI. According to Caves, rival firms in an oligopoly with product differentiation tend to follow

⁴ In addition, Campa's model predicts a positive effect of the rate of change in the exchange rate on FDI, as well as negative effects of both the variable costs of production and sunk costs.

⁵ According to the literature on foreign investment, the exchange rate's effect on the investment decision depends on the country where the good is produced, the national source of the inputs used in its production, and the country where the final good is sold. See, for example, Caves (1989).

⁶ For a full explanation of the empirical measures of all the variables, please refer to Campa (1993).

⁷ In the limited empirical literature on the link between exchange rates and FDI, Froot and Stein (1991) and Klein and Rosengren (1994) also find evidence of a significant relationship.

each other in making direct investments in foreign countries.⁸ For example, a foreign firm may find the investment environment of a US industry favorable and decide to enter that industry. As the first foreign firm enters the US industry, rival firms may also find the investment environment favorable and follow suit. The opposite may happen if a foreign firm finds a better investment environment in markets outside the US. A foreign firm may then find the US industry to be unfavorable to FDI and instead consider other markets. Rival firms may also find the investment environment in the US to be unfavorable. Hence, rival firms may view an industry as favorable or unfavorable to FDI depending on whether their competitors viewed an industry as favorable or unfavorable to FDI in the previous period.

In the context of corporate rivalry in FDI, whether a foreign firm finds the investment environment of a US industry favorable or unfavorable may depend not only on the investment environment in the US but also on other factors such as its home investment environment, its interactions with its rivals in markets outside the US, and political actions of governments affecting it but not its rivals. Since these factors include the interactions among foreign firms and governments as well as changing conditions in various markets, they are difficult to measure and subject to a great deal of uncertainty. Hence, it is impractical to include all these factors as regressors in a model that explains FDI.⁹

The central focus of our paper is to reexamine the relationship between the exchange rate and FDI taking into account **the possible interdependence of FDI over time**. This interdependence is described by the **Markov zero-inflated Poisson (MZIP) model** developed by Wang (2001). More specifically, we model the interdependence of FDI over time as a **two-state Markov process in which the two states can be interpreted as either a favorable or an unfavorable environment for FDI in an industry in the US**. The Markov process incorporates the factors affecting the two states that are difficult to measure and subject to uncertainty. Significantly, we address the reclassification of four-digit SIC industry codes after 1987 by constructing an unbalanced panel data set. Consequently, the number of industries in our sample is greater during 1988–1994 than 1982–1987. We use Campa (1993) as our basic empirical framework. Our results clearly show evidence of interdependence of FDI over time and, most critically, our findings empirically reconfirm a significant impact of the real exchange rate on FDI.

⁸ Caves points out that the existence of local production facilities can give a foreign firm a competitive edge in marketing its product. For example, local production may enable the firm to better adapt its product to the local market and provide ancillary service of higher quality or lower cost.

⁹ Other than political actions of governments, Caves (1971) notes that another source of uncertainty is the high costs of information about foreign markets, which causes foreign firms to make FDI decisions with incomplete information—even as incomplete information on foreign markets is difficult to measure. Caves also mentions exchange rate changes as a source of uncertainty. However, as in Campa (1993), exchange rate uncertainty may be represented in regressions by the standard deviation of the change in the log of the exchange rate.

II. Data, MZIP Model, and Empirical Framework

A. FDI Data

Our basic empirical framework is Campa's (1993) empirical implementation of the theoretical model developed by Dixit (1989). Our FDI data are industry-level panel data of FDI into the US. Our data sources and specification of empirical variables are based largely on Campa although there are some differences, which we explain below. Following Campa, we eliminate the influence of input origin, production location, and output destination on the relationship between FDI and exchange rate by considering FDI into the US wholesale trade sector rather than the manufacturing sector. Data on FDI in the wholesale trade sector is from the International Trade Administration's (ITA) publication entitled, "Foreign Direct Investment in the United States: Completed Transactions" (US Department of Commerce, various years). The ITA publication includes information on the type of investment, the name and nationality of the foreign investor, the name of the US affiliate, the US affiliate's four-digit SIC code, and the value of investment in US dollars.¹⁰ However, the ITA publication has many missing observations on the values of investments due to confidentiality agreements with foreign investors. Because of this, we use the number rather than the value of FDI in four-digit SIC industries in the wholesale trade sector.¹¹

Following Tomlin, we extend the sample period to cover 1982 to 1994.¹² Due to the reclassification of some four-digit SIC industry codes after 1987, we have 59 and 69 industries for 1982–1987 and 1988–1994, respectively. It is important to emphasize that we handle the post-1987 reclassification by constructing an unbalanced panel data set that contains more SIC four-digit industries for 1988–1994 than 1982–1987.¹³ Fourteen additional SIC industries were created after 1987 while four SIC industries were discontinued after 1987. For each year and each industry, we enter as our observation the number of FDI. We have 389 nonzero entries or observations from 1982 to 1994, which show foreign investors from 32 countries making 1,111 investments in the US wholesale trade sector. However, there are years when an industry does not have FDI recorded in the ITA publication. When there is no FDI in a certain year, we enter zero as our observation for that year. We have 405 zero observations making up 51% of our total observations. Our sample has a size of 794 observations.

¹⁰ The types of investments are acquisition and mergers, equity increase, joint venture, new plant, plant expansion, real estate, and other categories.

¹¹ Other than Campa (1993), Blonigen (1997), Tomlin (2000), and Klein et al. (2002) also use the number of FDI instead of the dollar values of FDI from the ITA publication.

¹² The last year in our expanded sample period is 1994 since ITA stopped publishing firm-level FDI transactions that year.

¹³ The full list of industries for the two subperiods is available from the authors upon request.

B. MZIP Model

To formally describe the possible interdependence of FDI over time and handle the large number of zeros in our data, we adopt a count data model known as the MZIP model developed by Wang (2001). The MZIP is based on the ZIP regression models. The ZIP model is used to handle count data with large number of zeros but the model is not valid when there is interdependence of observations over time. Unlike the ZIP model, the MZIP model allows for the interdependence of observations over time. Since the ZIP model may be regarded as a special case of the MZIP model, we can examine the interdependence of FDI over time by comparing the two models using the Akaike information criterion (AIC) proposed by Akaike (1974). A smaller value of the AIC for the MZIP model than the ZIP model would indicate that MZIP model is more appropriate and thus lend support to the interdependence of FDI over time.

As noted earlier, our MZIP model describes the interdependence of FDI over time as a **two-state Markov process**. The two states are a favorable and an unfavorable environment for FDI in an industry in the US. The Markov process incorporates the factors affecting the two states, which are difficult to measure and subject to uncertainty. Since the MZIP model was first designed for a time-series specification but we use industry-level panel data for our empirical analysis, we formally redefine the MZIP model for panel data. The Appendix explains the MZIP model and its application to panel data in greater detail.

C. Empirical Framework

Our two variables of interest are the rate of FDI and the Markov transition probability. The FDI rate refers to the number of FDI per period and the Markov transition probability refers to the transition from the state in one period to the state in the next period. We define p_{00} as the probability of transition from an unfavorable FDI environment to an unfavorable FDI environment, p_{01} as the probability of transition from an unfavorable environment to a favorable environment, and so forth. As noted earlier, we use Campa's empirical model as our basic empirical framework. The biggest difference is that we use the MZIP model whereas Campa uses the Tobit model. The determinants of the FDI rate and transition probabilities in our analysis are the same variables used by Campa. Those determinants are measures of exchange rate level R_{it} , rate of change in the exchange rate μ_{it} , volatility of the exchange rate σ_{it}^2 , sunk costs k_{it} , and unit labor costs of the US relative to foreign countries w_{it} . We can summarize Campa's reduced form function of FDI projects in industry i at time t - y_{it} - to be estimated, which is instructive for own MZIP regression, along with the expected signs of the coefficients, as below.

$$y_{it} = \phi \left(\begin{array}{ccccc} \mu_{it}, & \sigma_{it}^2, & R_{it}, & k_{it}, & w_{it} \\ + & - & + & - & - \end{array} \right) \quad (1)$$

The definitions and computations of the three exchange rate variables (R_{it} , μ_{it} , and σ_{it}) are based on Campa. More specifically, we define the exchange rate level R_{it} as the average of the exchange rate in the year of the FDI, μ_{it} as the trend in exchange rate, and σ_{it} as the standard deviation of the monthly change in the logarithm of the exchange rate. Since μ_{it} and σ_{it} incorporate firms' expectations about the future levels of those variables, their computation requires assumptions about how firms form such expectations. As in Campa (1993), we make two alternative assumptions: perfect foresight and static expectations. The former implies that firms have perfect forecast expectations of the ex-post value of the exchange rate for the next 2 years. The latter implies that firms estimate the future exchange rate as the exchange rate in the 2 years previous to the FDI.¹⁴ Following Campa, the exchange rate variables are computed using monthly index of foreign currency per US dollar and weighted by the number of FDI (International Monetary Fund 2004). Campa provides a detailed discussion of the FDI weights for the exchange rate variables. When the number of FDI is positive for an industry in a particular year, we calculate an effective exchange rate as the average of the exchange rate indexes weighted by the number of FDI from a given country.

However, there are two main differences between our and Campa's computations of the three exchange rate variables. First, our base year for computing those variables is 1995 whereas Campa's base year is 1980. Second, and more importantly, we differ from Campa in terms of the data source we use to calculate the FDI weights for the three variables when there is no FDI. If the number of FDI is zero for an industry in a particular year, we calculate an effective exchange rate using weights based on the total number of firms from a foreign country operating in that industry from 1973 up to that year. We choose 1973 since it is the first year for which data are available from the ITA's "Foreign Direct Investment in the United States: Completed Transactions". This data source provides FDI data for four-digit SIC industries. In contrast, Campa uses a data source providing three-digit SIC data, from which he estimates the four-digit SIC data needed to compute the FDI weights. More specifically, Campa uses the 1980 benchmark survey of the US Department of Commerce, Bureau of Economic Analysis, "Foreign Direct Investment in the United States: Operations of US Affiliates: 1977–1980". Our FDI weights are likely to be more accurate since our data source provides four-digit SIC data whereas Campa's data source provides three-digit SIC data.

Let us now look at the variables that are not related to exchange rates, namely sunk costs k_{it} and foreign variable costs w_{it} . While sunk costs k_{it} are a theoretically important determinant of FDI, they are difficult to measure empirically. We use the two empirical proxies for industry-specific sunk costs proposed by Campa. $SUNK_{it}$ is the ratio of fixed assets to net wealth of all US firms in a four-digit SIC industry and represents all the physical investments that a firm has to incur to establish itself in the market (see Robert Morris Associates [1982] for 1981 data; and Dun's & Bradstreet [various years] for other years' data). ADV_{it} is the ratio of media expenditures to company sales by all US firms in

¹⁴ Tomlin refers to what Campa calls static expectation as adaptive expectation.

a four-digit SIC industry and represents largely unsalvageable nonphysical investments in advertising, sales force, and media promotion (US Federal Trade Commission 1985). We compute both $SUNK_{it}$ and ADV_{it} exactly as described in Campa. Our measure of the variable production cost is unit labor cost, w_{it} , as in Campa. However, in computing w_{it} , we use the weighted average of the unit labor cost indexes of 11 countries with respect to the US rather than 10 as in Campa. Furthermore, we use a more up-to-date version of Campa's data source, namely the Bureau of Labor Statistics (2002, table 10). The weights are the proportion of FDI from a given country in each four-digit SIC industry.¹⁵

III. Empirical Results

A. Static Expectations

We first examine the interdependence of FDI over time for the case of static expectations, which means that firms estimate the future exchange rate as the exchange rate of the year previous to the FDI. To check for evidence of interdependence of FDI over time, we compare the MZIP and the ZIP regression models. The MZIP allows for such interdependence whereas the ZIP model does not. The two models have the same determinants of the average FDI rate as well as for the transition probabilities in the MZIP model and the zero probability, i.e., the probability of an unfavorable FDI environment, in the ZIP model. Table 1 below reports the results. The top half of the table reports the estimated coefficients for the FDI rate, while the bottom half reports the estimated coefficients for the transition probabilities of the MZIP model and the zero probability in the ZIP model.

The left side of the bottom half of Table 1 shows that the AIC of the ZIP model is larger than the MZIP model when there are no restrictions on the coefficients. This suggests that the MZIP model is more appropriate and thus provides some support to the interdependence of FDI over time. Most of the regressors of the transition probabilities are insignificant even at the 10% level. **Since our results suggest that the coefficients of the regressors in transition probabilities may be zero, we fit the data to a restricted MZIP regression with these coefficients equal to zero. The results of the restricted MZIP model are also shown in Table 1. For comparison, we also run the ZIP regression with restricted coefficients for the zero probability. As in the unrestricted models, the MZIP model is the preferred model in terms of AIC. We use the likelihood ratio test to compare the unrestricted MZIP model with the restricted MZIP model. Since the log-likelihood ratio test statistic is 13.2 with the p-value of 0.358, we cannot reject the restricted MZIP in favor of the unrestricted MZIP. Hence, the restricted MZIP model is the most appropriate model.**

¹⁵ When there is no FDI, we compute the weights as we do for the three exchange rate variables.

Table 1: Markov Zero-Inflated Poisson and Zero-Inflated Poisson Regression Results for Static Expectations

Variable	Unrestricted Coefficients		Restricted Coefficients	
	MZIP	ZIP	MZIP	ZIP
Constant	0.982**	1.106**	0.996**	1.120***
Exchange rate level	0.784***	0.748***	0.786***	0.783***
Trend in exchange rate	-0.309	-0.314	-0.394	-0.404*
Standard deviation in exchange rate	-0.725	-0.760	-1.089	-1.310
Unit labor costs	-0.367	-0.473*	-0.386	-0.508*
Sunk costs	-0.019***	-0.018***	-0.018***	-0.019***
Advertising expenses	-0.167***	-0.168***	-0.163***	-0.162***

	Transition Probabilities		Zero-Probability	Transition Probabilities		Zero-Probability
	p_{00}	p_{11}	p	p_{00}	p_{11}	p
Constant	-0.365	-0.215	0.286	0.851***	0.926***	-0.273***
Exchange rate level	-0.401	0.531	-0.700			
Trend in exchange rate	1.384	-1.751	0.895			
Standard deviation of exchange rate	12.501*	-4.086	6.073*			
Unit labor costs	1.050	0.538	-0.016			
Sunk costs	0.002	0.003	0.004			
Advertising expenses	0.043	0.077	-0.051			
Log-likelihood	-1376.2	-1422.8		-1382.8		-1428.5
AIC	2794.4	2873.6		2783.6		2873.0

***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

ZIP = Zero-Inflated Poisson, MZIP = Markov Zero-Inflated Poisson, AIC = Akaike Information Criterion.

Note: All the variables are described in greater detail in Section II. p_{00} (p_{11}) refers to the probability that an unfavorable (favorable) FDI environment in the previous period will remain unfavorable (favorable) in the current period in the MZIP model. Zero-probability, p , refers to the probability of an unfavorable FDI environment in the ZIP model.

Using the logit function, we compute the transition probabilities of the restricted MZIP model p_{00} , p_{01} , p_{11} and p_{10} to be 0.701, 0.299, 0.716, and 0.284, respectively.¹⁶ The probability that an industry is in the FDI-unfavorable state in one period when it was in the same state in the previous period is thus 70.1%. Similarly, the probability that an industry is in the FDI-favorable state in one period when it was in the same state in the previous period is thus 71.6%. Such numbers lend support to the interdependence of FDI over time. Our results also imply that in the long run an industry is in the FDI-unfavorable state 48.7% of the time, and in the FDI-favorable state 51.3% of the time since the stationary probabilities of the states of the Markov chain are $p_0 = 0.487$ and $p_1 = 0.513$, respectively.¹⁷

¹⁶ For example, $p_{00} = \text{logit}(0.851) = e^{0.851}/(1 + e^{0.851}) = 0.701$, $p_{01} = 1 - p_{00} = 0.299$.

¹⁷ After calculating the transition probabilities, we can calculate the stationary probabilities of the two states of the

$$\text{Markov chain, } p_0 \text{ and } p_1 \text{ from } \begin{pmatrix} p_{00} & p_{01} \\ p_{10} & p_{11} \end{pmatrix} \times \begin{pmatrix} p_0 \\ p_1 \end{pmatrix} = \begin{pmatrix} p_0 \\ p_1 \end{pmatrix}.$$

Let us now turn to the top half of Table 1 and the regression results of the FDI rate function. Those results indicate the effects of the different determinants of FDI in industries with favorable FDI environments. The left side reports the estimated coefficients when there are no restrictions on the transition probabilities regressors. The estimates are quantitatively similar for the MZIP and the ZIP models, and have the expected signs except exchange rate trend. However, inferences about some parameters differ between the two models. For example, at 10% significance level, the coefficient of the unit labor costs is not significant for the MZIP model, but significant for the ZIP model. Since we found the MZIP model to be more appropriate than the ZIP model, using the ZIP model may lead to incorrect inferences about the parameters.

For the more appropriate MZIP model, the coefficients of the exchange rate level and trend are positive while the coefficient of the exchange rate standard deviation is negative. The coefficients of both measures of sunk costs and labor costs are negative. The t-statistics indicate significance at the 1% level for the exchange rate level, which has the expected positive sign. Both measures of sunk costs have the expected signs and are significant at the 1% level. Although the exchange rate trend is unexpectedly negative, it is not significant. Exchange rate standard deviation and unit labor costs have the expected signs, but are insignificant even at the 10% level. Our most notable result is the positive and highly significant coefficient of the exchange rate level, which suggests that a stronger currency attracts more FDI inflows.

The right side of the top half of Table 1 reports the parameter estimates when the coefficients of the regressors in the transition probabilities of MZIP are restricted to be zero, for reasons outlined above. The results for the restricted coefficients are broadly consistent with the results for the unrestricted coefficients. Furthermore, as was the case for the unrestricted coefficients, the estimates of the restricted coefficients are quantitatively similar for the MZIP and ZIP models. Again, our most significant result is the positive and highly significant coefficient of the exchange rate level, which implies that currency appreciation is conducive to FDI inflows. For the restricted MZIP model, which we found to be the most appropriate model, when an industry is favorable to FDI, the average rate of FDI is given by:

$$\mu_{it} = \exp(0.996 + 0.786R_{it} - 0.394\mu_{it} - 1.089\sigma_{it} - 0.3861w_{it} - 0.018SUNK_{it} - 0.163ADV_{it}) \quad (2)$$

B. Perfect Foresight

Table 2 below reports our results for the case of perfect foresight, which means that firms have perfect forecast expectations of the ex-post value of the exchange rate of the next year. The top half of the table reports the estimated coefficients for the FDI rate and the bottom half reports the estimated coefficients for the transition probabilities

of the MZIP model and the zero probability in the ZIP model. As in the case of static expectations, **we first check for the interdependence of FDI by comparing the results of the ZIP and the MZIP models for the transition probabilities. For both restricted and unrestricted coefficients, the AIC is larger for the ZIP model than the MZIP model. This implies that the MZIP is more appropriate than the ZIP, and thus lends support to the interdependence of FDI over time.**

The MZIP results for the unrestricted coefficients indicate that the regressors for the transition probabilities are mostly insignificant. The statistical insignificance of the regressors suggests that we should restrict their coefficients to be zero, as we did for static expectations. The right-bottom of the table reports the parameter estimates, log-likelihood, and AIC of the MZIP when we restrict the coefficients. **To compare the unrestricted and restricted MZIP models, we conduct the likelihood ratio test. Since the test statistic is 7.2 and the p-value is 0.846, we cannot reject the null hypothesis that the coefficients of the regressors of the transition probabilities are zero. This suggests that the restricted MZIP model is the most appropriate model, as was the case for static expectations.** Using the logit function, we compute the transition probabilities p_{00} , p_{01} , p_{11} , and p_{10} to be 0.700, 0.300, 0.717, and 0.283, respectively. The estimated transition probabilities support the notion that FDI may be interdependent over time. Furthermore, the long-run probability of a favorable and unfavorable FDI environment is 51.4% and 48.6%, respectively.

The top half of Table 2 reports the estimated coefficients of the MZIP and ZIP models for the FDI rate function. For both restricted and unrestricted coefficients, our MZIP regression results for the average rate of FDI in industries with favorable FDI environments are consistent with theoretical predictions. All the estimated coefficients have the expected signs. The t-statistics indicate significance of the exchange rate level and both measures of sunk costs at the 1% significance level, and insignificance of the unit labor costs as well as exchange rate trend and standard deviation. The estimates for the ZIP models are quantitatively similar to those for the MZIP models. The results for the perfect foresight case are thus broadly similar to those for the static expectations case and further reinforce our most significant result, namely a positive and highly significant effect of the exchange rate on FDI. For the restricted MZIP model, the most appropriate model, the average rate of FDI is given by:

$$\mu_{it} = \exp(0.757 + 0.932R_{it} + 0.235\mu_{it} - 1.503\sigma_{it} - 0.263w_{it} - 0.018SUNK_{it} - 0.162ADV_{it}) \quad (3)$$

Table 2: Markov Zero-Inflated Poisson and Zero-Inflated Poisson Regression Results for Perfect Foresight

Variable	Unrestricted Coefficients		Restricted Coefficients	
	MZIP	ZIP	MZIP	ZIP
Constant	0.773*	0.856*	0.757*	0.821*
Exchange rate level	0.918***	0.904***	0.932***	0.948***
Trend in exchange rate	0.264	0.279	0.235	0.282
Standard deviation in exchange rate	-1.373	-1.344	-1.503	-1.514
Unit labor costs	-0.265	-0.352	-0.263	-0.358
Sunk costs	-0.018***	-0.018***	-0.018***	-0.018***
Advertising expenses	-0.167***	-0.167***	-0.162***	-0.162***

	Transition Probabilities		Zero-Probability	Transition Probabilities		Zero-Probability
	P_{00}	P_{11}	P	P_{00}	P_{11}	P
Constant	1.093	-0.786	1.198	0.849***	0.930***	-0.266***
Exchange rate level	-0.233	0.884	-1.056**			
Trend in exchange rate	0.667	-0.131	-0.516			
Standard deviation of exchange rate	-4.551	-4.288	2.002			
Unit labor costs	0.352	0.844	-0.368			
Sunk costs	0.001	-0.001	0.006			
Advertising expenses	0.038	0.079	-0.046			
Log-likelihood	-1378.9		-1423.3	-1382.5		-1427.8
AIC	2799.8		2874.6	2783.0		2871.6

***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

ZIP = Zero-Inflated Poisson, MZIP = Markov Zero-Inflated Poisson, AIC = Akaike Information Criterion.

Note: All the variables are described in greater detail in Section 2. p_{00} (p_{11}) refers to the probability that an unfavorable (favorable) FDI environment in the previous period will remain unfavorable (favorable) in the current period in the MZIP model. Zero-probability, p , refers to the probability of an unfavorable FDI environment in the ZIP model.

C. Overall Empirical Evidence

Our two main empirical findings are the interdependence of FDI over time and a positive relationship between the exchange rate and rate of FDI inflows in industries, which are favorable to FDI. Our computed Markov transition probabilities suggest that FDI inflows into US wholesale trade industries may be interdependent over time because of uncertainty over **whether an industry's environment is favorable or unfavorable to FDI**. This uncertainty could be modeled as a two-state Markov chain. More precisely, if an industry had been favorable to FDI in the previous period, it is more likely to be favorable to FDI in the present period and likewise for the probability of an industry being unfavorable to FDI.

Our MZIP regression results show that for industries with favorable FDI environments, most of the coefficients of the regressors of the rate of FDI have the expected signs, and

some of the coefficients are highly significant. In particular, under both static expectations and perfect foresight, the exchange rate level has a positive and significant impact on the rate of FDI. This suggests that a stronger US dollar has a positive impact on the rate of FDI into US wholesale industries. Our findings thus reconfirm the empirical results of Campa for exchange rate level. Like Campa, we find unexpectedly negative coefficients for the exchange rate trend in the case of static expectations, although they are insignificant. Our estimated coefficient for exchange rate standard deviation is negative but insignificant. Hence, we do not find evidence to support Dixit's (1989) hypothesis that exchange rate uncertainty deters the average rate of FDI.

Our findings also differ from those of Tomlin for the ZIP regressions. Our ZIP regression results suggest a positive significant impact of the exchange rate level on the rate of FDI. This might seem puzzling at first since Tomlin also uses ZIP regressions. However, we should keep in mind that we use panel data while Tomlin uses pooled cross-sectional data. Furthermore, we address the issue of post-1987 SIC reclassifications by building up an *unbalanced* panel data set and construct the three exchange rate variables on the basis of more accurate FDI weights. In any case, it is more appropriate to use the MZIP model since using the ZIP model may lead to incorrect inferences about the parameters when FDI is interdependent over time.

IV. Concluding Remarks

Common sense tells us that the real exchange rate has an effect on FDI, just as it has an effect on international trade. A number of theoretical and empirical studies have examined the relationship between FDI and the real exchange rate more formally. In particular, Campa develops an empirically testable model of FDI based on Dixit's model of investment, which in turn is derived from the theory of option pricing in financial economics. Campa's model predicts, and the empirical evidence from his Tobit estimation strongly supports, a significant effect of the real exchange rate on the probability of FDI entry in US wholesale trade industries. However, using the ZIP model, Tomlin fails to find a meaningful relationship between the exchange rate and the average rate of FDI. Our study expands the ZIP model by incorporating the possibility of interdependence of FDI over time in each industry. **To do so, we use the MZIP model, which is based on two-state Markov chains.** For empirical purposes, we extend the MZIP model, which is a time-series specification, for panel data since we use industry-level panel data for our empirical analysis. While our data are based largely on Campa, there are some differences. It is also important to point out that we use an unbalanced panel data set.

One of our two main empirical findings is that FDI is indeed interdependent over time. Such interdependence captures immeasurable and uncertain factors that affect the state of an industry—whether firms view an industry as favorable or unfavorable to FDI—and,

in turn, these views may be affected by the state of the industry in the previous period. As mentioned earlier, corporate rivalry may explain such interdependence. Our second main empirical finding is that when industries are favorable to FDI, the exchange rate level has a positive and highly significant impact on the rate of FDI inflows. This implies that a stronger host-country currency may make investment more profitable for foreign investors who enjoy an increase in their home-country currency revenues. Further findings are that the other two exchange rate-related variables are not significant and both measures of sunk costs have significant negative effects on FDI.

If FDI is interdependent over time, a model such as the MZIP model that explicitly accounts for such interdependence is more appropriate for the empirical analysis of FDI. Our evidence does indeed provide strong support for the interdependence of FDI over time. Our study thus suggests that the ZIP model may be inappropriate for the analysis of panel FDI data since it may result in incorrect inferences about parameters. In line with Campa's findings but in contrast to Tomlin's findings, we find that the exchange rate level has a significant effect on the rate of FDI inflows into the US. Although there are theoretical grounds for both a positive and negative effect of the exchange rate on FDI, in the case of the US wholesale trade sector, our results clearly lend support to a positive effect. This implies that a stronger US dollar will promote FDI inflows into the US wholesale trade sector. At a broader level, our analysis points to a need for future researchers to incorporate possible interdependence in FDI over time when they examine the determinants of FDI. Doing so will strengthen the robustness of their findings.

Appendix: Application of the MZIP Model to Panel Data

We extend the Markov Zero-Inflated Poisson (MZIP) model developed by Wang (2001) to panel data with k subjects or industries. Let $\{(y_{ij}, x_{ij}, t_{ij}); j=1, \dots, n_i\}$ be a sequence of observed data for industry i ($i = 1, \dots, k$), where y_{ij} is an observed foreign direct investment (FDI) count associated with time exposure of t_{ij} during the j th period and a vector of covariates $x_{ij} = (x_{ij}^{(1)}, x_{ij}^{(2)})$ for $j \geq 2$ and $x_{i1}^{(1)} = x_{i1}^{(2)}$ where the dimensions of vectors $x_{ij}^{(1)}$ and $x_{ij}^{(2)}$ are d_1 and d_2 , respectively. The MZIP model for panel data assumes that:

- (i) for an observed FDI count y_{ij} for industry i during period j , there corresponds a partially observed binary random variable, S_{ij} , representing the condition of a two-state discrete time Markov chain with $S_{ij} = 1$ when $y_{ij} > 0$ and $S_{ij} = 0$ when $y_{ij} = 0$. Furthermore, we define the state represented by $S_{ij} = 0$ as the zero state in which industry i is not favorable to FDI, and the state represented by $S_{ij} = 1$ as the Poisson state in which industry i is favorable to FDI;
- (ii) the partially observed binary random vector $(S_{i1}, S_{i2}, \dots, S_{in})$ for industry i follows the two-state discrete time Markov chain with transition probabilities defined by

$$\begin{aligned} \Pr(S_{ij}=0 | S_{i(j-1)}=0) &= p_{00}(ij) \\ &= \frac{\exp(\beta_0' x_{ij}^{(1)})}{1 + \exp(\beta_0' x_{ij}^{(1)})} \equiv \text{logit}(\beta_0' x_{ij}^{(1)}), \end{aligned} \quad (1)$$

$$\Pr(S_{ij}=1 | S_{i(j-1)}=0) = p_{01}(ij) = 1 - p_{00}(ij) \quad (2)$$

$$\begin{aligned} \Pr(S_{ij}=1 | S_{i(j-1)}=1) &= p_{11}(ij) \\ &= \frac{\exp(\beta_1' x_{ij}^{(1)})}{1 + \exp(\beta_1' x_{ij}^{(1)})} \equiv \text{logit}(\beta_1' x_{ij}^{(1)}) \end{aligned} \quad (3)$$

$$\Pr(S_{ij}=0 | S_{i(j-1)}=1) = p_{10}(ij) = 1 - p_{11}(ij) \quad (4)$$

where $\beta_0 = (\beta_{01}, \dots, \beta_{0d_1})$ and $\beta_1 = (\beta_{11}, \dots, \beta_{1d_1})$ are two unknown parameter vectors related to the transition probabilities $p_{00}(ij)$ and $p_{11}(ij)$ respectively; and

- (iii) conditional on $S_{ij} = 1$, observed FDI count y_{ij} follows a Poisson distribution

$$f_1(y_{ij} | x_{ij}^{(2)}, t_{ij}, \alpha, S_{ij} = 1) = \frac{1}{y_{ij}!} [\lambda(x_{ij}^{(2)}, \alpha) t_{ij}]^{y_{ij}} \exp[-\lambda(x_{ij}^{(2)}, \alpha) t_{ij}] \quad (5)$$

where $y_{ij} = 0, 1, \dots, \lambda(x_{ij}^{(2)}, \alpha) = \exp(\alpha' x_{ij}^{(2)})$, and $\alpha = (\alpha_1, \dots, \alpha_{d_2})$ is an unknown parameter vector; conditional on $S_{ij} = 0, y_{ij} \equiv 0$, i.e.,

$$f_0(y_{ij} | S_{ij}=0) = \begin{cases} 1 & \text{if } y_{ij}=0 \\ 0 & \text{if } y_{ij} > 0 \end{cases} \quad (6)$$

Under the above assumptions, the likelihood function of the model is

$$I = \prod_{i=1}^k [p_0^{(i1)} f_0(y_{i1} | S_{i1}=0) + p_1^{(i1)} f_1(y_{i1} | x_{i1}^{(2)}, t_{i1}, \alpha, S_{i1}=1)] \\ \prod_{j=2}^{n_i} \{[p_{00}(ij) + p_{10}(ij)] f_0(y_{ij} | S_{ij}=0) + [p_{01}(ij) + p_{11}(ij)] \\ f_1(y_{ij} | x_{ij}^{(2)}, t_{ij}, \alpha, S_{ij}=1)\} \quad (7)$$

Note that while $p_0^{(i1)} = \Pr(S_{i1}=0)$ and $p_1^{(i1)} = \Pr(S_{i1}=1)$ are the unknown probabilities of the initial states of the Markov chain for industry i , we assume that both initial states are equally likely and set $p_0^{(i1)} = p_1^{(i1)} = 0.5$. Our Monte Carlo simulation study, which we do not report here, indicates that the values of probabilities have little effect on parameter estimates for a large sample.¹⁸ Also, as in Wang (2001), a sequence of repeated observations over time for a subject is modeled by the MZIP model for a time series, and the serial dependence of repeated observations for a subject is described by the hidden Markov chain. The series of repeated observations for different subjects in a panel data set are assumed to be independent of each other.

¹⁸ The results of the Monte Carlo study are available from the authors upon request.

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About the Paper

Joseph D. Alba, Donghyun Park, and Peiming Wang uncover two main findings in their empirical analysis of the impact of exchange rates on foreign direct investment (FDI) inflows. First, FDI inflows are interdependent over time. Second, the exchange rate has a positive and highly significant impact on FDI inflows, due to the beneficial effect of a stronger host-country currency on the home-country currency revenues of foreign investors.

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