Heterogeneous Information and Investment under Uncertainty **

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Abstract

A sudden change in investment environment shifts objective uncertainty (characterized by parameters that determine the distribution of returns) and at the same time heightens subjective uncertainty (about the data generating parameters) unevenly across investors. For a given state of economy, the uncertainty facing the investor is the sum of the uncertainty in the data and the uncertainty of the investor's assessment of the expected return distribution. In this model the option value of waiting to invest depends not only on the objective uncertainty as in the traditional theory but varies systematically with investor information and Bayesian updating of outlook for the project. Simulation of the model suggests that during a state characterized by greater uncertainty and higher potential expected return investment will be by an abnormally high percentage of informed investors and may increase overall. For over 10,000 instances of firm-level FDI data for Korea from 1996 to 2001, regression results are consistent with the hypothesis that disproportionably more FDI is made by experienced (hence more informed) investors during heightened uncertainty.

Keywords: uncertainty, investor information, option value, Bayesian updating, FDI.

Journal of Economic Literature Codes: D8, E22, F21.

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1. Introduction

In the famous 'option value of waiting under uncertainty' investment models of McDonald and Siegel (1986), Dixit (1989), and Dixit and Pindyck (1994), investors have perfect information on the parameters in the model that generates signals.[1] In reality, identifying and collecting information on potential projects and assessing whether making an investment is worthwhile represent substantial obstacles and expenses to investment; therefore the investors' information on the projects is far from perfect. In this paper we will present a model of investment under uncertainty in which investors must deal with two types of uncertainty: the objective uncertainty in the data (the luck of the draws from the model given the parameters) and the subjective uncertainty about the data generating model (i.e., the uncertainty about the parameters that determine the distribution of the draws). With a sudden change in environment or a regime change, subjective uncertainty is likely to be substantially increased, and by much more for some agents than for other agents. We are interested in studying how an investor's response to objective uncertainty depends on the degree to which an investor's subjective uncertainty is raised and the extent of his information about the data generating model.

The key difference between our model and the option value theory of investment under uncertainty lies in investor's information structure. Investors are assumed to update their information from observations of signals and this influences their decision on whether to invest. Unlike the standard investment problem, the option value of waiting depends not only on the

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[1] Other papers have considered multiple sources of uncertainty within the context of irreversible and partially irreversible models of investment. Bertola and Caballero (1994) show that for irreversible investment the required return is higher when the price of new capital is more volatile. In the partially irreversible investment model presented in Bloom *et al* (2007) in which firm-level investment response to policy and demand shocks is more cautious during periods of high uncertainty.

objective uncertainty, but also on investor's information and Bayesian updating on the project.[2] The investor's uncertainty on the prospect of the project diminishes as the investor observes more signals of the project. For an informed investor, the uncertainty is small and the threshold of return that triggers investment is lower than that of an uninformed investor.

In our model, even when different investors observe the same macroeconomic data, their responses to changes in the macroeconomic environment are dependent on their subjective uncertainty. If the subjective uncertainties are time varying across investors, then there does not exist a stable empirical relationship in the aggregate response of the investors to changes in macroeconomic variables. Informed investors tend to be more sensitive to macro-uncertainty than less informed investors. The investor's knowledge makes a particularly large difference when the economy is in a state characterized by greater uncertainty and higher potential expected return. Simulation of the model suggests that in the wake of such a state total investment may increase and will be characterized by an abnormally high percentage of investment by informed investors.[3]

Bayesian updating of subjective uncertainty is not a new concept, neither is the notion that time-varying objective uncertainty affects optional value of an investment. But the empirical implications of the theory in the present paper, that investors' subjective uncertainty influences the timing of investment, are rarely tested, mainly because of lack of good proxies of investors' subjective uncertainty on investment projects. Our empirical test of the theory is based on firm

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[2] Bayesian learning has been applied in macroeconomic models in a number of contexts. Jovanovic (1979) and Prescott and Townsend (1980) provide theoretical analysis of labor market equilibrium when workers' productivity is learned over time through Bayesian updating. In an infinite period optimal control setting, Easley and Kiefer (1988) and Weiland (2000) show how policy makers should conduct experiment to draw inference about the parameters in the economy through Bayesian learning in the process of maximizing the posterior expectation of an objective function.

[3] Some extensions of Dixit and Pindyck (1994) obtain the outcome that increases in uncertainty will increase investment. For example, Abel et al's (1996) options model of partially irreversible investment generates the result that given a potentially favorable resale price of capital, an increase in investment might be generated by a rise in uncertainty.

level FDI data where an investing firm's subjective uncertainty can be proxied by the investment history it experienced with the host firm. Our test shows that investor experience plays a prominent role in FDI decision in a time of heightened uncertainty.

Our empirical test is based on micro-data on inward FDI to Korea during and after the 1997 Asian financial crisis. The behavior of the Korean won/US dollar exchange rate is extraordinary over 1997-1998. Figure 1 shows the sharp depreciation of the Korean won relative to the US dollar over 10 year period for monthly data beginning in 1991. Before the collapse of the Korean won during the financial crisis, the currency was under a managed floating exchange rate regime where daily fluctuation of the spot rate was restricted within a band relative to the U.S. dollar. During the Asian financial crisis, the won/dollar rate jumped from 965 in October of 1997 to 1695 in December 1997 before settling down to about 1200 in the beginning of 1999. The sharp depreciation of the won made assets denominated in the Korean currency much cheaper for foreign investors from the end of 1997 through 1998, but was also a period characterized by considerable uncertainty about the data generating model.

Figure 1: Exchange Rate (Korean won/U.S. dollar): three-month moving average
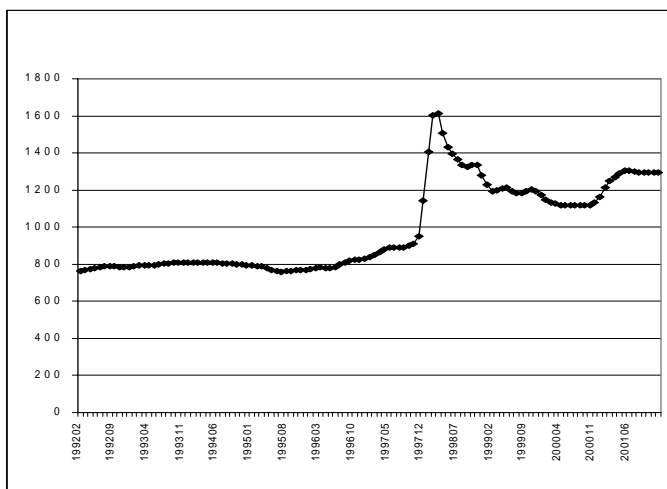
Despite the heightened uncertainty, FDI to Korea in the twelve month period after the outbreak of crisis in November 1997 jumped by 70% in U.S. dollar value over that of the

preceding period twelve months. A disproportionably high fraction of the FDI made immediately following the crisis came from foreign investors with previous experience in Korea compared to foreign investors with no previous experience in Korea. Thus, during a period of heightened uncertainty informed investors act with the most opportune timing.

From data in earlier years we identify 30% of the 10,405 instances of firm-level FDI in Korea between 1996 and 2001 as being by investors with experience. FDI by investors with experience tends to be larger and constitutes over 50% of the value of the $36.6 billion dollar inward FDI total to Korea over 1996-2001. We conduct regression analysis to estimate the marginal effects of the macro-factors on FDI conditioning on the investors' information in two types of models: FDI event counts modeled by a negative-binomial regression; and the likelihood that a given FDI incidence with a particular investor feature is modeled as a binomial logit regression. In the negative-binomial regressions, we find that the number of FDI counts from experienced investors is much more responsive to changes in exchange rates and exchange rate uncertainty than that from inexperienced investors. In the binomial logit regressions, we find that FDI made at time of heightened exchange rate uncertainty and FDI of large size are more likely to be by the experienced foreign investor. The results confirm that information of investors is a critical determinant of firm-level FDI response to the exchange rate during a period of heightened uncertainty.

The rest of the paper is organized as follows. Section 2 presents a model of investment under uncertainty with Bayesian learning. Section 3 describes the FDI data. Section 4 presents a brief review of the literature on the relationship between FDI and the exchange rate. Section 5 presents estimates of negative binomial and multinomial logit regression models of FDI. Section 6 concludes.

2. A Model of Investment under Uncertainty with Bayesian Learning

2.1 The Specifics of the Model

In the model an investor observes a signal of expected return to a project, and chooses between investing in the project in the current period and waiting to reconsider investment in the next period. The investor must deal with the objective uncertainty in the data given the model and the subjective uncertainty about the data-generating model.[4] To highlight the importance of the role of investor's information, we set up a model in which all uncertainty in data depends on the state of the macroeconomy. The macroeconomic shock generates a signal for each project. The signal comes from the same distribution but may be different ex-post for each project. The investors may respond differently to the same observed signals, due to difference in investor information. The expected return depends on the state of the economy and on an investor's assessment of the impact of the state of the economy on the return of his prospective project. There are two states of the macroeconomy; a high uncertainty state and a normal state. When the economy is in the high uncertainty state, or crisis state for emphasis, the potential expected return has a macroeconomic scaling factor $M_t = m_1$ that is larger than that in the normal state m_2. The value of M is known in each period to investors. Suppose in period t the economy is in crisis (in state s=1) then the variance of the draw $\sigma_t^2 = \sigma_C^2$ is larger than that under a normal state, $\sigma_t^2 = \sigma_N^2$. If the macro state is s_j (j=1 or 2), then expected return is given by

$$x_t = \rho M_t + \varepsilon_t, \tag{1}$$

where ε_t follows a normal distribution with mean zero and variance σ_t^2, $N(0, \sigma_t^2)$. The

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[4] The model differs from that in McDonald and Siegel (1986), Dixit (1989), and Dixit and Pindyck (1994) in which investors know the model that generates signals. In the benchmark model of an infinite horizon continuous time framework with the return following the Brownian motion (the continuous time version of discrete time random walk) there exists an analytical solution for optimal timing of investment.

transition probabilities for economy-wide uncertainty of the next period (*j*) conditioning on the current state (*i*) are given by $p_{i,j}$, with $\sum_{j=1}^{2} p_{i,j} = 1$ for (*i*=1,2).

A key assumption is that the mean of the expected return, ρM, is unknown to the investor because the parameter ρ is unknown. When the economy is hit by a crisis, the potential return (indicated by *M*) is higher, but the impact on the project is not known to the investor. [5] Some projects are more affected by crisis than others. The investor's information plays a more important role in making precise assessment at the time of crisis. The investor learns about the implication of the state of the economy on the project under consideration as more data become available over time. The new data are combined with prior information through Bayesian learning. The prior information of the investor before observing any data is assumed to be a normal distribution $\pi_0 \sim N(\rho_0, \omega_0^2)$. This initial prior may be different for different investors. The other source of the difference in investors' information is the number of observations drawn from the project at a given state of the economy. The period-t prior about the parameter ρ (before observing the signal in the period) is denoted as π. The investor's knowledge (the posterior) after observing the period-t signal is denoted by π'. The normality of the posterior follows from that of the model and the normality of the prior.

An investor has two possible courses of action. First, he may make the investment in the current period; second, he may wait to the next period before taking any action. Without causing

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[5]The assumption that a crisis raises potential expected mean is the more interesting situation to analyze. It also provides a parallel with our empirical example. First, in the Asian crisis the sharp depreciation of domestic currency is temporarily far beyond the long term purchasing power parity level, so that overall FDI becomes inexpensive. Second, the Korean FDI data show that in the wake of crisis overall FDI increased. It is plausible to assume that a large number of investors believed that the potential return is increased despite the atypical uncertainty. Note that the assumption of increase in potential expected return does not imply the expected return for each project is higher, due to the randomness in parameter ρ. Furthermore, the conclusion that the informed investors have lower threshold of required return still holds if we assume the potential expected is not increased by the crisis.

confusion, we drop the subscript that represents the state of the economy. Let $V(s,x,\pi)$ be the value of project when the current expected return is x and the variance of x is σ^2 in state s conditioning on parameter ρ. The next period expected return is x'. The dynamic programming problem is characterized by the following Bellman's equation:

$$V(s,x,\pi) = \max\{x,0, EV(s',x',\pi'| s,x,\pi)/(1+r)\}. \qquad (2)$$

The value of waiting before discounting, $EV(s',x',\pi'| s,x,\pi)$, is the conditional expectation with respect to the macro state of the next period (s'), the next period's signal (x'), and the posterior (π') of parameter ρ, given the current macro-state (s), the observed signal (x), and investor's prior (π).

The normality of the prior of ρ implies that it can be captured by the mean and variance parameters, with $\pi \sim N(\bar{\rho},\bar{\omega}^2)$. The updating of investor's knowledge (from π to π') is based on the Bayes rule. Given the current macro-state s, the investor knows M and σ but not ρ. The investor also observes the signal from a host (or project) given in (1), x. Then given the prior $\pi \sim N(\bar{\rho},\bar{\omega}^2)$, the posterior follows a normal distribution:

$$\pi(\rho| s,x,\pi) \propto \exp\{-\frac{(x-\rho M)^2}{2\sigma^2}\}\exp\{-\frac{(\rho-\bar{\rho})^2}{2\bar{\omega}^2}\} \propto N(\bar{\rho}',\bar{\omega}'^2).$$

Here the variance of the posterior

$$\bar{\omega}'^2 = (\bar{\omega}^{-2} + M^2\sigma^{-2})^{-1}. \qquad (3)$$

The mean of posterior

$$\bar{\rho}'= (\bar{\omega}')^2(\bar{\rho}\bar{\omega}^{-2} + xM\sigma^{-2}). \qquad (4)$$

The Bayesian updating implies a shrinking posterior variance ($\overline{\omega}' < \overline{\omega}$), i.e., as the investor observes more data, his uncertainty about the parameter ρ is reduced. There is a reduction in posterior mean if the observation is lower than the prior mean ($\overline{\rho}' < \overline{\rho}$ if $x < \overline{\rho}M$).

The solution of the optimal investment problem (2) can be characterized by a threshold x^* at which the investor is indifferent in making investment and waiting, $x^* = EV(s', x', \pi' | s, x^*, \pi)/(1+r)$. If $x > x^*$ then it is optimal to invest. The optimal threshold depends on the investor's assessment of parameter uncertainty and the state of the economy. The overall uncertainty of the investor about x' of the next period is given by the predictive density of x', defined as $f(x' | s_i, x, \pi) = \sum_{j=1}^{2} p_{i,j} \int l(x' | \rho, s_j) \pi(\rho | s_i, x, \pi) d\rho$, obtained through weighing the normal likelihood of x' for each value of parameter ρ by the posterior of ρ after current period observation of x at state s_i. The result is a mixture of normal distributions:

$$f(x' | s_i, x, \pi) = \sum_{j=1}^{2} p_{i,j} N(\overline{\rho}' M_j, \sigma_j^2 + M_j^2 \overline{\omega}'^2). \qquad (5)$$

Equation (5) shows that for each given state of economy, *the uncertainty in the investor's predicted draw of signal of the next period is the sum of the uncertainty in data, σ^2, and the uncertainty of investor's assessment in the mean of the expected return, $M^2 \overline{\omega}'^2$.*

The condition (5) shows that with smaller posterior variance, $\overline{\omega}'^2$, the variance of predicted x' is smaller, and the value of option for waiting is lower. The investor's knowledge makes a particularly large difference when the economy is in the crisis state because the posterior variance $\overline{\omega}'^2$ is amplified by the higher potential expected return M_j. In the absence of subjective uncertainty about parameter ρ, $\overline{\rho}'$ becomes the true parameter value of ρ and $\overline{\omega}'$ becomes zero. In this case the problem becomes one of standard value of option for investment, where the only

source of uncertainty is the state of the economy and the luck of the draw for the project given the state of the economy. Under this scenario, the standard conclusion that increases in uncertainty σ raise the threshold of required returns follows.

The substance of this section is summarized in the following remarks. First, in the standard investment problem, the investor has perfect knowledge about the parameters of the distributions that generate draws for returns to a project, which determines the option value of waiting. In the present model the option value of waiting depends on the investor's uncertainty on the prospect of the project, and the uncertainty diminishes as the investor observes more signals of the project (as the updating formula (3) implies). For an informed investor, the uncertainty $\overline{\omega}$ is small and the threshold of x that triggers investment is lower than that of an uninformed investor. This means that for the same macroeconomic uncertainty, the informed investors are more likely to commit funds than uninformed investors.

Our model suggests that larger macro-uncertainty raises the option value of waiting for two reasons. First, the heightened uncertainty makes option more valuable given investor's knowledge about the prospect of the project. Second, the updating formula (3) shows that if the crisis amplifies project uncertainty σ more than potential return M, then the signal x becomes noisier in the crisis period, and the precision of the posterior is improved more slowly, which also makes waiting more desirable.

2.2 A Numerical Example

To examine the properties of the theoretical model intuitively, we will now present some numerical results on the optimal policy. We draw the expected return x using model (1). We then simulate the distribution of the threshold of the experienced investor, x^*, and calculate the number of cases that have the threshold x^* above the simulated data x.

We assume for the normal (non-crisis state) M=0.5 and σ_N =0.05; for the atypical or crisis state M=1.0 and σ_N =0.2. If the economy is at the crisis state, the probability of staying in such state is 0.8; and if the economy is at a normal state, the probability of staying in such state is 0.999. We let the discount rate r=0.01. Simulations show that higher discount rates produce qualitatively the same result. We consider the case that there are 4 types of investor firms, each numbers 10,000 in period t=1. The four types of firm observe draws from the same distribution of expected returns governed by (1), with the parameter $\rho = 0.2$ and face the same macro state. A type i investor firm (i=1,..4) is characterized by an ex-ante identical initial prior parameter ρ centered at 0.2 but with a standard deviation ranging from 0.1 for type 1 to 0.7 for type 4. By design, the only difference across potential projects ex-ante is the investor's uncertainty concerning the prospect of the project.

For each potential project, we simulate 5 periods of expected returns from model (1) and update the investor's posterior for the parameter ρ. The realized states are: crisis for t=1, and normal states for t=2, 3, 4, 5. We start the simulation at the crisis state so that the numbers of investors with given information sets at the time of crisis can be perfectly controlled. Therefore ex-post difference in investment decisions across different types of investor firms is solely due to the initial information sets of investors. A more realistic model assumption is that for each firm the initial prior for parameter ρ is dependent on the state of the macroeconomy, hence only observing signals from a project during normal state of the economy does not help in reducing the investor' uncertainty about the project when the economy switches to a crisis state. By starting at a crisis state, we can avoid the complicating assumption of state-dependent initial priors and still produce simulation results that are approximately consistent with such a model. In the simulation, if the expected return drawn is above the threshold level given the current

posterior of investor uncertainty and macro state, then the project is funded and taken out of the pool of 10,000 potential projects. To evaluate the conditional expectation in (2), we use 10 point Gauss-Hermit quadrature to proxy distribution of continuous random variable, which is appropriate for normally distributed errors. We found through experiments that the approximation is highly accurate and much faster than grid search method.

Simulation Results of Investment with Heightened Uncertainty (10,000 Potential Projects)

Standard deviation of initial prior (Higher number indicates less experience)	Count of invested projects		
	During crisis period	During 4 periods after the crisis	Total over time
0.1	3198	3675	6873
0.3	2358	3490	5848
0.5	1540	3731	5271
0.7	1030	3886	4916
Total count of Investment	8126	14782	22908

Note that the analysis of the theoretical model indicates that investor's uncertainty about parameter ρ is reduced over time as more data are observed, and the threshold of the expected return is lower when the investor's uncertainty is lower. Investors' initial priors reflect a high degree of uncertainty and it takes more observations to reduce the posterior variance of ρ to a given level. It follows that these investors tend to take longer to decide to invest for a given set of observed data. When a financial crisis hits the economy, the mean and the variance of expected return are both high. As equation (5) shows, the uncertainty for the signal of next period is given by the sum of (objective) macro uncertainty σ^2 and (subjective) investor's project-specific uncertainty $\overline{\omega}^2 M^2$. For an investor with a high subjective uncertainty ($\overline{\omega}^2$), the higher potential return M amplifies the overall uncertainty. For an investor with a small $\overline{\omega}^2$, the larger potential

return mainly represents a profitable opportunity. It is more likely that the informed investor will take advantage of the higher potential return.

The simulation results confirm the above intuition. Note that the data for all investors are generated from the same distribution. But the most informed investors (with smallest standard deviation of 0.1 in the initial prior) made more investment (close to 32% of them did so) in the crisis period than the least informed investors with the largest standard deviation of 0.7 in the initial prior (only about 10% of them did so). If the first group is labeled as informed (or experienced) investors, and the rest as less experienced investors, then during the crisis period investment from the experienced investors account for 39% (3198 out of 8126) of the total cases, and after the crisis only 25% (3675 out of 14782).

Note that for the sake of simplicity, the theoretical model ignores many important factors in investment decisions, and should be viewed as illustrative instead of empirical. We will not try to strictly match the numerical simulation with the Korean data for that reason. The change in macro uncertainty and the mean of expected return affect the investors' decision. The regression results reported later in the paper give marginal effect of the shifts in macro uncertainty (in exchange rate) and shifts in the mean of expected return, controlling other factors. One factor omitted from the theoretical model is the cost of information acquisition. We assume that in every period there is one signal observed without cost. In reality, assessment on investment projects typically involves substantial costs that may prevent many investors from obtaining new information on a regular basis. If the cost of information acquisition per dollar of investment is negatively correlated with the size of the investment, then one should expect large FDI to occur relatively more frequently around the time of crisis.

2.3 Empirical Implications

The above model is useful for analyzing the response of experienced investors to a shock in the expected return, given the specific information of investors. The corresponding empirical question to which we apply the model concerns the marginal effect of a shock in exchange rate to foreign direct investment. With heightened uncertainty, a favorable exchange rate is accompanied by greater macro uncertainty. The subjective uncertainty about the expected returns is amplified by the increase in the parameter M. This effect is smaller for informed investors. But the increase in M generates higher expected return for given ρ. Combining these two aspects of the theory, we conclude that informed investors respond more quickly to the crisis. This implication of the model will be examined in subsequent sections.[6]

3. The Korean FDI Data

Data on inward FDI to Korea is from *Invest Korea, Korea Trade and Investment Promotion Agency* in the *Ministry of Commerce, Industry & Energy*. The data set records the date and amount of inward FDI for Korea and is monthly. Between January 1996 and December 2001, there are 10,405 observations on FDI. Data are available on FDI for several earlier years, but this data set is used to identify FDI events in the period starting in January 1996 as being first-time or repeat FDI by investors.[7] A substantial cost in making FDI is the intangible cost in collecting information on potential projects which we believe is influenced by the experience of the foreign investor.[8] The specific affiliation characteristics of a foreign investor firm is its

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[6] In trade theory, Rauch and Trindade (2003) show that improved information makes trade more responsive to international price differentials. Our argument on the exchange rate and FDI is analogous to their argument.

[7] Some foreign investors have started investing in Korea prior to January 1996, in which case their FDI activity during the sample will be correctly identified as experienced rather than as first-time.

[8] These costs include the foreign investor being required to file notification to the *Korea Investment Service Center* (KISC) or to domestic and overseas trade centers of KOTRA (*Invest Korea, Korea Trade and Investment Promotion Agency*). The notification within the scope of industries permitted for foreign investment appears to be a formality. At the time of notification, tangible costs of incorporation expenses are on average 3% in metropolitan areas and about 2% outside metropolitan areas (Invest Korea).

experience in making FDI in Korea, including repeated FDI experience with a specific host firm, and whether or not it has managerial control over the host firm.

Table 1 reports the size distribution of FDI events over 1994:11-2001:10, with data reported annually starting in November so as to capture behavior over the financial crisis reflected in accelerated deterioration in the value for the Korean won starting in November of 1997. A striking feature of the data in Table 1 is that the dollar value of FDI from November, 1997 to October, 1998 was 70% higher than FDI in the immediately preceding twelve months. The size distribution exhibits an interesting time-varying pattern in that the average size of FDI is larger in the post-crisis period starting in November 1997 than in the 12-month period immediately before the financial crisis.

Table 2 shows the counts and amounts of FDI made over 1996:1-2001:12 grouped by investor experience profile. Of all 10,405 FDI events, 3119 events were by investors as second or subsequent experiences of FDI in Korea. Cases with FDI made by an investor with experience are 30.0% of the number of cases and 50.7% of the amount of FDI. Furthermore, Table 2 shows that the count of FDI involving the same investor/host firm pair (at their second and subsequent interactions) is 2418. Thus, the great majority of experienced investors repeat FDI with the same host firm. These "paired" foreign investor firms are likely to be the most informed investors.

It is striking that during the short period following outbreak of the Asian Financial crisis in Korea during which the won is at its lowest value, 1997:11-1998:7, the share of total FDI in value by investors with paired experience is 52.4%, higher than the 35.9% share for the pre-crisis period 1996:1-1997:10 and the 40.1% share for the post-crisis period 1998:8-2001:12. Experienced investors played an especially prominent role in a short period after the crisis, and the combination of value and count of FDI suggests that individual FDI by investors with

experience is larger than that by inexperienced investors. These observations are consistent with the implications of the model of investment with heterogeneous information and heightened uncertainty presented in Section 2.

The counts data in Table 2 shows that for the sample period, FDI counts from investors with experienced in the host firm make up 23.3% (2418/10405) of total FDI incidences. For the short-sample period 1996:1-1998:10 (before the relaxation of capital controls), FDI counts share from the same experienced investor group is 37.7% of total FDI incidences. The numbers suggest that the composition of the FDI cases during the crisis is substantially different from the whole sample period. The counts of FDI larger than one million dollars and are made by experienced investors for the sample period 1996:1-1998:10 make up 15.4% of total FDI counts, for the whole sample it is 10%. As we note above, during the short period of the crisis, FDI from experienced investors makes up a larger share of total FDI. Furthermore, 45.1% of all of FDI incidence from the experienced investors takes place during the short period while 27.8% of all FDI incidence and 23.9% of FDI from inexperienced investors take place during the period 1996:1-1998:10.

The cross time and cross sectional dimensions of the FDI incidence motivates the regression analyses of the present study. The negative binomial regression captures the variation of counts of FDI by one type of investor with macroeconomic variables, and the binomial logit regression captures the variation of monthly composition of FDI cases from experienced and inexperienced investors. The regressions are based on the whole sample period 1996:1-2001:12 as well as the shorter period 1996:1-1998:10. Note that the estimates for the shorter period reflect the variations of FDI counts or share of FDI from experienced investors to macroeconomic

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uncertainty within that period, so we learn more about the marginal effect of the macroeconomic uncertainty beyond that reflected by the summary statistics across different sample periods.

The role played by experienced foreign investors during the crisis is illustrated in Figure 2 with a plot of the 3-month moving average of the percentage of the count of FDI by foreign investors with paired experience in total count of FDI over the period 1996-2001. During the crisis period (November 1997 to July 1998), the share of counts of investors with paired experience in total counts of FDI shows a sharp increase compared to the pre-crisis period. As the economy stabilized, FDI cases from inexperienced investors dominated and the share of FDI from experienced investors steadily declined, until near the end of the sample period, when both exchange rate and uncertainty rose again, as Figure 1 shows.

Figure 2: Fraction of FDI count by experienced foreign investors 1996:01-2001:12

The surge of FDI by inexperienced investors at the end of 1998 is reinforced by the relaxation of capital control by the Korean Government in November 1998. Since the 1980s, the Korean government has adopted a series of measures of capital liberalization. On regulations concerning FDI, a new FDI regime passed by National Assembly on September 2nd, 1998, and effective November 17th, 1998 was a landmark event. This legislation instituted policies

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designed to expedite and encourage FDI through tax advantages, reduction in restrictions and red tape, and opening of previously restricted sectors. These changes reduce the cost of FDI in Korea.[9]

Finally, in review of the data, we note from Table 2 that the story of FDI in Korea over 1996:1-2001:12 is overwhelmingly about foreign investors making investment in unlisted host firms (that are not publicly traded) rather than in listed firms on KSE and KOSDAQ. A firm is taken as foreign-owned if it bears the same name as the foreign investor. Of 4099 FDI received by foreign-owned firms, only 30 FDI were received by foreign-owned firms listed in Korea. Unlisted (majority owned) domestic firms received 6068 FDI and listed firms received 268 FDI (including the 30 FDI to foreign-owned listed firms).

4. Brief Review of Literature on FDI and the Exchange Rate

In recent years a wealth of theories and empirical tests has been developed on how Foreign Direct Investment (FDI) responds to changes in macroeconomic variables.[10] The emphasis in the literature is to examine the relationship between FDI and the exchange rate for given firm-specific characteristics. A positive association between depreciation and inward FDI is hypothesized in influential papers by Froot and Stein (1991), through the role of imperfect

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[9] The tax and other incentives are targeted for larger FDI projects and for projects in certain sectors such as the high technology industries. Foreign investors benefit from exemption on rent and fees, as well as support for residential facilities such as medical, education and housing support. In designated Foreign Investment Zones foreign investors also benefit from outstanding infrastructure such as roads, railways, airports, seaports, utilities, and telecommunication facilities.

[10] Blonigen (2005) surveys empirical work on FDI determinants and emphasizes the need for more firm-level empirical analysis of hypotheses in the literature. The main insight from industrial organization regarding FDI is that it increases at the level of the firm the value of domestic assets, through better foreign management expertise, better monitoring of the management, and easier adoption of technology. Caves (1971) surveys and assesses these arguments. Razin and Sadka (2002) theorize that foreign companies are better at evaluating the prospects of domestic firms. Mody et al. (2002) show with country-level data that foreign investors have information advantages in countries having low corporate governance and accounting standards. Lipsey (2000) notes that inward and outward FDI tend to move together, suggesting that that the primary function of FDI is allowing for efficient foreign owners to gain control of domestic companies rather than financing capital formation. In the classic work by Dunning (1988) on the ownership, location, and internalization framework of the multinational firm, the exchange rate influences FDI through effects on costs of production, and in Markusen (2002) the location of stages of production is determined endogenously by where factors of production used intensively are relatively cheap.

financial markets and financially restricted domestic firms, and by Blonigen (1997), based on goods markets imperfections generating differential value to foreign and domestic investors of firm-specific assets. The literature on the effect of increased uncertainty about the exchange rate on FDI has either proceeded by considering risk-averse firms making investment decisions prior to the resolution of uncertainty as in Cushman (1985) and Goldberg and Kolstad (1995), with effects depending on firm-specific assumptions, or has been based on options theory developed by Dixit (1989) and Dixit and Pindyck (1994) as in Campa (1993), with a rise in uncertainty about exchange rates causing a delay in FDI.

In the model of investment under uncertainty with Bayesian learning in this paper, experience influences investor response to shifts in expected return and uncertainty induced by changes in the macro economy. Familiarity with investment in a particular industry and region being relevant for subsequent FDI has been addressed by a number of authors. Blonigen et al. (2005) report that investment within a region by a Japanese manufacturing firm's *Keiretsu* group increases likelihood of further investment in that region by that firm.[11] Chang and Rosenzweig (2001) and Barkema and Vermeulen (1998) report that experience influences entry mode by foreign firms into the U.S. electronics and chemical industries and by large Dutch firms into many countries, respectively. That FDI is a sequential process with significant agglomeration benefits is well established in the literature.[12] However, consideration of how investor response

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[11] In related work, Kogut and Chang (1996) find that the likelihood of an investment by Japanese firms in U.S. electronic industries is greater if the firm has made previous investments. Belderbos and Sleuwaegen (1996) find that Japanese investment in Southeast Asia is significantly influenced by inter-firm connections.

[12] In early contributions to the literature on the multinational firm, Davidson (1980) finds that prior experience in a country is likely to increase a firm's investment in that country and Kogut (1983) argues that decisions by multinational companies to initially establish a plant in a country are motivated by considerations that may differ from those influencing subsequent investment decisions. Head et al. (1995) has emphasized the importance of agglomeration benefits in FDI decisions. Clearly the issue of experience and agglomeration effects in determining FDI is related to the issue of trade networks with emphasis on a search process developed by Rauch (1999).

to the exchange rate is influenced by investor experience with FDI has not appeared in the literature.

The empirical work on the influence of the level and uncertainty of the exchange rate on FDI yields results that vary across country and time. Empirical work by Blonigen (1997), Kogut and Chang (1996), Goldberg and Kolstad (1995), Klein and Rosengren (1994), Froot and Stein (1991), and Cushman (1985), amongst others, mostly on FDI flows at the aggregate and/or industry level, finds that dollar depreciation leads to increased FDI into the U.S., with the implication that this is a robust result.[13] Less numerous than investigations of the effect of the exchange rate on FDI, empirical results on the effect of volatility of exchange rates on FDI vary, with Cushman (1985) and Goldberg and Kolstad (1995) finding a positive association and Campa (1993) finding the reverse.

5. Regression Analysis

In this paper we use two types of regression models to explore different dimensions of the data on the link between the exchange rate and inward FDI to Korea over 1996:1-1998:10 and 1996:1-2001:12. These periods contain greater volatility of the exchange rate than those that have normally been analyzed in connection with FDI. We estimate macro and firm-specific effects on the FDI case-counts to different categories in a negative-binomial regression and the probability that a given FDI incidence belongs to a particular category in a binomial logit regression.

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[13]In an exception to the general findings for the U.S., Dewenter (1995) using transaction-specific data reports that the real exchange rate is not correlated with FDI to the U.S. for most industries when overall investment and corporate wealth are controlled. Studies on sensitivity of inward FDI to the real exchange rate for other OECD countries report fewer statistically significant results than for the U.S. For example, Froot and Stein (1991) find statistically insignificant effects for the UK, Canada, and Japan. For developing countries, Kiyota and Urata (2005) report heterogeneous findings among researchers on the effects of the exchange rate and uncertainty (measured by exchange rate volatility) on FDI.

5.1. Modeling the Monthly FDI Counts: The Negative Binomial Model

We are interested in exploring how the FDI counts to different firms respond to changes in macro variables such as exchange rates. The count data are often modeled by Poisson process. Preliminary examination of Poisson models shows substantial over-dispersion.[14] As a result, we consider the negative binomial model for each type. The negative binomial model has a number of economic applications, e.g., see Hausman et al. (1984) and Blonigen (1997). Suppose the FDI cases of a given type j in period t is n_{jt}. The negative binomial model is given by NB(γ_{jt}, δ_j), where $\gamma_{jt} = \exp(X_t \beta_j)$ is the mean, and δ measures over-dispersion. When the dispersion parameter approaches zero, the negative binomial model becomes Poisson.

5.1.1 Macroeconomic variables

Macroeconomic variables, X_t, that will be taken to influence FDI include the exchange rate, volatility of the exchange rate, and a measure of capital control by the Korean government. The 3-month moving average of the Korean won/U.S. dollar exchange rate will be used to indicate expected exchange rate.[15] The logarithm of a 3-month moving average of the standard deviation of the daily change in the won/dollar exchange rate each month, $L(sdex)$, will serve as a proxy for uncertainty about the exchange rate. The realized day-to-day volatility of the exchange rate is a reasonable way of capturing uncertainty about future values of the exchange rate. As a robustness check we will also use a 3-month moving average of exchange rate volatility estimated by GARCH, $L(garch)$, as an alternative measure of exchange rate

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[14] The values of Pearson Chi-sq and deviance divided by the degrees of freedom are significantly larger than 1 in all cases.

[15] Cushman (1985), Froot and Stein (1991), Klein and Rosengren (1994), and Blonigen (1997) investigate the effect on FDI of the current (real value) of the exchange rate. Campa (1993) measures expected exchange rate by either (perfect foresight) of exchange rate over next 2 years or static expectation based on past two years.

volatility.[16] Figure 3 indicates that both $L(sdex)$ and $L(garch)$ peak during the early stages of financial crisis (with $L(sdex)$) peaking somewhat before $L(garch)$), exhibit considerable volatility throughout the 1996:1-2001:12 period, and move in line the exchange rate in Figure 2.

Figure 3: Exchange rate volatility measures: 1996:1-2001:12
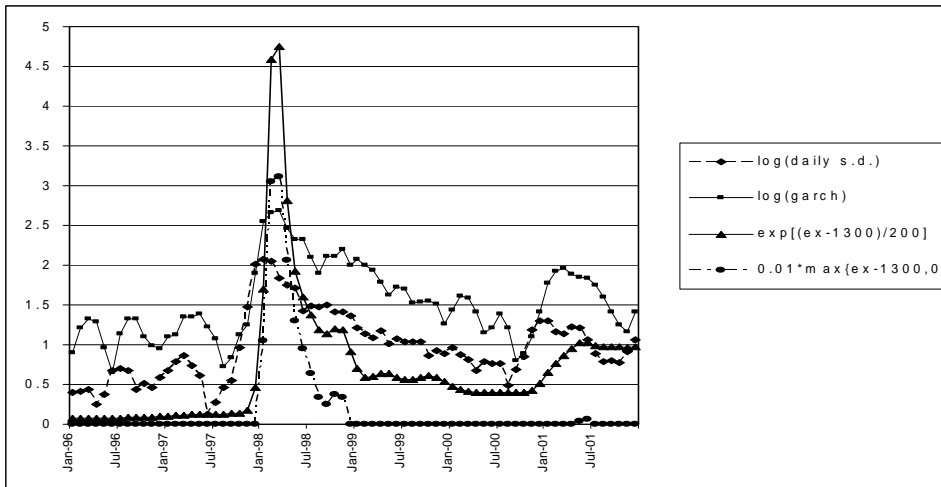
During the Asian financial crisis, the Korean won lost about half its value against the U.S. dollar within two months and rebounded steadily in the next three years following the collapse. On December 3, 1997, in agreement with the IMF the Central Bank of Korea is instructed to support the won whenever the won/dollar rate goes above 1300.[17] A won/dollar rate of 1300 was seen as representing a substantial devaluation and values in excess of 1300 were viewed as excessive relative to the 800 to 900 levels that had prevailed over several years prior to November 1997. The won/dollar rate exceeded 1300 on December 8, 1997 and would not fall

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[16]A survey of measures of exchange rate volatility used in the FDI literature can be found in Kiyota and Urata (2004). Campa (1993) measures exchange rate volatility as the standard deviation of monthly change in the logarithm of the exchange rate. Goldberg and Kolstad (1995) measure exchange rate volatility as the normalized standard deviation of twelve quarters of the real exchange rate prior to and inclusive of the current quarter. Cushman (1985) introduces the average level of "surprise" as a measure of uncertainty given by the deviation of the currently observed real exchange rate from that expected, in addition to measuring volatility in the exchange rate by the standard deviation of quarterly changes in the real exchange rate within the current year.

[17] During the Asian crisis the IMF set target levels for the exchange rate and Korean interest rates were to be raised whenever the won/dollar rate exceeded 1300.

below 1300 again until July 7, 1998. To provide further robustness checks of our results we will use two additional indicators of uncertainty beside $L(sdex)$ and $L(garch)$. If ex is the 3-month moving average won/dollar exchange rate, the additional measures of volatility are monthly series given by $V(\exp) \equiv e^{\{(ex-1300)/200\}}$ and $V(\max) \equiv 0.01 \max\{ex - 1300, 0\}$. The first measure of uncertainty captures a non-linearity, in that deviations of the exchange rate from 1300 indicate proportionately greater uncertainty than indicated by the amount ex exceeds 1300, and the second measure of uncertainty captures a non-linearity confined mostly to the period of the financial crisis, when ex repeatedly exceeds 1300. These measures of exchange rate volatility are shown in Figure 3.

A capital control index, cc, set at zero up through 1998:10 and set at 1 after 1998:10, is included in X_t. In order to isolate the effect of relaxation of capital controls from the crisis period negative binomial and binomial logit regressions will be reported for 1996:1-1998:10, a period that embraces the financial crisis and immediately precedes the new era of relaxed capital control, and for 1996:1-2001:12, a sample period for the capital control index, cc, will be introduced as an explanatory variable.

5.1.2. FDI case counts by experience

MLE estimates of (β, δ) in negative binomial regressions are obtained and reported for count of FDI by investor and host firm with different levels and combinations of experience in Table 3. For the explanatory variables that are in logarithm, the estimates can be interpreted as an approximation of elasticity of the expected FDI counts with respect to the explanatory variables.

In Table 3A negative binomial regressions are reported for 1996:1-1998:10. Regressions for total count of FDI, for count of FDI by investors with no experience, for count of FDI by investors with paired experience (the investor and host firm have prior FDI with each other

implying that FDI is a second or subsequent FDI), and for count of large FDI (FDI over one million dollars) by investors with paired experience are labeled (i)-(iii), (iv)-(vi), (vii)-(ix), and (x)-(xii). A dummy variable to capture the financial crisis, *Crisis*, set at 1 over 1997:11-1998:7, and zero otherwise, has a positive coefficient that is statistically significant at the 10% level of confidence for count of FDI for all agents. The coefficient of *Crisis* is positive and statistically significant at the 1% level of confidence for count of FDI by investors with paired experience and is not statistically significant for count of FDI by investors with no experience. These results indicate that the increase in FDI during the financial crisis in Korea is driven by that for experienced investors relative to that by inexperienced investors. The coefficient on *Crisis* is greatest for large FDI by experienced investors, a group likely to have the greatest information on investment prospects.

The exchange rate (*Lex*, the logarithm of *ex*) has a statistically significant positive coefficient in regression (ii) in Table 3A. This result suggests that a devaluation of 10% leads to a 3.7% increase in total FDI count. In contrast, a 10% devaluation leads to a 5.3% rise in FDI count by investors with paired experience (regression (viii)) and to a 10.4% increase in the count of large FDI by investors with paired experience (regression (xi)). Uncertainty about the exchange rate (*L(sdex)*) also significantly raises FDI count by investors with paired experience with a more marked effect for large FDI within this group (from regressions (ix) and (xii)).[18] *Lex* and *L(sdex)* are not statistically significant in the regressions for FDI by inexperienced investors.

In Table 3B we report negative binominal regression results for monthly FDI count over 1996:1-1998:10 for the same groups as in Table 3A, but for different measures of volatility of

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[18] *Lex* and *L(sdex)* are positively correlated and their appearance in the same regression results in imprecise estimates with neither variable being statistically significant. These results are not reported.

the exchange rate. The result that experienced investors have a statistically significant positive response to increased volatility of the exchange rate, whereas inexperienced investors do not have a statistically significant response is robust across the alternative measures volatility.

In Table 3C we report negative binominal regression results for monthly FDI count over 1996:1-2001:12 for the two groups appearing in Table 3A that had the most divergent results, i.e., for the count of large FDI by investors with paired experience and count of FDI by investors with no experience. In the regression equations in Table 3C a capital control dummy is introduced to control for the change in capital control regime in November 1998. A positive value for cc indicates a relaxation of capital control. For the most part a relaxation of capital control resulted in a statistically significant increase in FDI count of both large FDI by investors with paired experience and FDI by inexperienced investors, but the coefficient for the inexperienced investors is of the order of 5 times as big as that for the count of large FDI by experienced pairs.

The results in Table 3C for the effect of devaluation and exchange rate volatility on count of FDI over 1996:1-2001:12 are very similar to those found in Tables 3A and 3B over 1996:1-1998:10. We find that over the period 1996:1-2001:12 large FDI by experienced investors has a statistically significant positive response to devaluation and to increased volatility of the exchange rate, but FDI by inexperienced investors does not. In results not reported, for the period 1996:1-2001:12 we attempted to distinguish the role of experience by foreign investors from that of the host firm, by considering regressions for FDI by experienced foreign investors (n=3119) exclusive of FDI by investors with paired experience (n=3119-2418=701) and regressions for FDI by experienced host firms (n=3180) exclusive of FDI by investors with paired experience (n=3180-2428=762). The exchange rate and exchange rate volatility were not statistically

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significant in influencing count of FDI to first-time host firms (foreign investors) from experienced foreign investors (host firms), suggesting that investors with paired experience is important in yielding sensitivity in count of FDI to devaluation and exchange rate volatility.[19]

5.2. Modeling Likelihood of FDI by experience: Binomial Logit Regression Model

In this section we will examine the impact of the exchange rate on the relative likelihood of different categories of experience of FDI with a binomial logit regression. This analysis will supplement that obtained from the negative binomial regressions on the effect of investor information on the connection between the exchange rate and FDI by allowing for the introduction of individual characteristics of size of FDI and whether the host firm is foreign or domestically owned.

We note that a binomial logit model gives probability that each case is true among a set of mutually exclusive scenarios, conditioning on a set of observed control variables. Although binomial logit is commonly used to model discrete choice of economic agents, such a behavioral interpretation is not intrinsically related to the model. The interpretation of the estimated conditional probabilities in this study is not about an investor's choice of being 'experienced' or 'inexperienced'. Instead, the estimates we present will capture the probability of a given incident of FDI falling into a particular category, conditional on macroeconomic variables and other the control variables. The 'reduced form' interpretation of the binomial logit means that the Independence from Irrelevant Alternatives (IIA) property (the ratio of the conditional probabilities of two categories is independent of other categories) is plausible.

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[19] FDI when both agents are experienced is dominated by experienced pairs, and the numbers are not great enough to distinguish paired from experienced foreign investors and experienced host firms that are non-paired even for the 1996:1-2001:12 period. In Table 2 count of FDI by paired agents (as second and subsequent FDI) is 2418 out of 2496 cases of FDI in which both investor and host have prior FDI experience (whether paired or not).

For a binomial logit model, let the dummy variables $d_j = 1, 2$ identify mutually exclusive and exhaustive categories of FDI. The likelihood of the type of FDI $D = (d_1, d_2)$ is given by binomial distribution, $\prod_{t=1}^{T} \prod_{j=1}^{2} p_{jt}^{D_{tj}}$, where $D_{jt} = 1$ if $d_j = 1$ and $D_{jt} = 0$, otherwise. The probability p_{jt} is characterized by a logit model $p_{1t} = \exp(z_t'\phi)/\{1 + \exp(z_t'\phi)\}$ and default normalization $p_{2t} = 1/\{1 + \exp(z_t'\phi)\}$, where z_t is a vector of economic factors that determine the probabilities p_{jt}, $(j = 1,2)$. By construction the logarithm of probability of FDI of type 1 over that of type 2 is given by $\log(p_{1t}/p_{2t}) = z_t'\phi$.

5.2.1 Microeconomic variables

Existing unlisted (majority owned) domestic firms are probably more likely to be open to potential inexperienced investors than are existing unlisted foreign (owned) firms. The influence on the probability that an FDI made to a domestic firm is by an experienced investor or not is recognized by introducing an indicator of type of host firm, *Domestic*, with *Domestic* =1 if the FDI host is an unlisted domestic firm, and 0 otherwise, into the vector z_t. Similarly, the log of size of individual FDI, *Lsize*, is also introduced into the vector of economic factors z_t.

5.2.2 Likelihood of FDI by experience

We will consider two categories of FDI that differ with regard to agent experience.[20] These categories are: $d_1 = 1$ if FDI is by investors with paired experience (investor and host firm have at least one FDI experience before time t) and 0 otherwise, and $d_2 = 1$ for all other FDI and 0 otherwise. Binomial logit regressions of the probability of whether FDI is more likely to be by

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[20] The groups are always mutually exclusive and exhaustive. Groups could be further subdivided into paired experience and the cases of an FDI involving experienced investors and inexperienced host firms, inexperienced investors and experienced host firms, no experience FDI. Not much is gained by this division that would come at the cost of adding more detail to Table 4.

an investors with paired experience rather than by all other investors (the default category) are reported in Table 4.

In Table 4A binomial logit regressions (i)-(iv) and (v)-(viii) are reported for 1996:1-1998:10 and for 1996:1-2001:12, respectively. The results indicate that with devaluation or a rise in exchange rate uncertainty, FDI is significantly more likely to be FDI by investors with paired experience relative to FDI by other investors, even when controlling for size of individual FDI and ownership of host firm. Thus, the results from the binomial regressions are consistent with those from the negative binomial regressions that experienced investors are more sensitive to high exchange rate volatility at a time of devaluation. The absence of FDI by inexperienced investors during the crisis, particularly as indicated in regressions (i)-(iv) in Table 4A for 1996:1-1998:10, a period preceding the relaxation of capital controls, indicates that there is a very high cost in searching and evaluating host firms.

In Table 4A, the log of size of individual FDI and the indicator of type of host firm are statistically significant. If an FDI is of large size, then it is significantly more likely to be associated with agents with paired experience. As expected, if an FDI involves a host that is a domestic firm then it is significantly more likely to be by an inexperienced investor. An alternative way of stating this result is that if FDI involves a host firm that is foreign owned, then it is significantly more likely to involve investors with paired experience. Put in this way, the finding is consistent with the observation by Lipsey (2001) that FDI is a relatively stable investment flow during crisis, and that experienced investors in foreign-owned firms make use of investment opportunities that allow them to grow rapidly.[21] FDI prompted by investors' information makes a valuable contribution to recovery from crisis.

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[21] New FDI is provided over 1997:11-1998:7, even though the premium for liquidity measured by the Korean short-term interest rate jumped from about 13% in November 1997 to 23% in December 1997, and fell back

In regressions (v)-(viii) in Table 4A, relaxation of capital control is found, as expected, to make it much more likely that FDI is by inexperienced agents. As the crisis passes, new and inexperienced investors attracted by a favorable exchange rate and easing of capital control start to accumulate in the Korean market. In Table 4B the results in Table 4A are found to be robust across different measures of exchange rate volatility.

The default category in Table 4, FDI by investors who are not investors with paired experience, is overwhelmingly first-time FDI by investors. From those making first-time FDI, ex post examination of data on first-time FDI by investors enables identification of those making one-time FDI and those who go on to become investors with paired experience by making subsequent FDI. In regression analysis not reported in the tables, we find that these two investor groups making first-time FDI do not react in different ways to the exchange rate. The results show devaluation is much more likely to result in FDI by investors with paired experience than by investors making FDI for the first-time, whether by investors who will eventually become experienced or by investors who will not participate in FDI again. However, results indicate that first-time FDI by what will become an investor with paired experience compared to first-time FDI that will turn out to be only one-shot FDI is likely to be significantly larger, more likely to establish a foreign-owned firm, and less likely when capital controls are relaxed.

The results of this empirical section can be summarized as follows: the negative binomial counts regressions and the binomial logit regressions confirm that information (indicated by experience) of investors influences response to the exchange rate and volatility in the exchange rate; the relationship between the exchange rate and FDI need not be stable over time and is

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to 12% only in July 1998. At the high premium there was evidence that liquidity was available. Borensztein and Lee (2002) with firm level data for Korea find no credit contraction in the first half of 1998. They find that total bank borrowing increased both in absolute terms and relative to other forms of finance for the average firm over the first half of 1998.

dependent on the mix of experienced and inexperienced foreign investors; capital controls are important regulatory barriers that keep relatively small inexperienced investors out of the domestic market and that policies to reduce the cost of finding an investor-host match could be a cost effective way of facilitating FDI.

6. Conclusion

In the model of investment under uncertainty with Bayesian updating presented in this paper, investors with different information take different courses of action with regard to investment. We argue that in situations in which there is a sudden change in environment, subjective uncertainty (about the model) is likely to be substantially and unevenly increased across investors. For a given state of economy, the uncertainty facing the investor is the sum of the uncertainty in the data and the uncertainty of the investor's assessment of the mean of the expected return. Investor response to objective uncertainty is shown to depend on the level of information an investor has about the data generating model.

Investors are assumed to update their information from observation of signals. This learning influences the decision on whether to invest. The investor's knowledge makes a particularly large difference when the economy is in a state characterized by greater uncertainty and higher potential expected return. Simulation of the model suggests that in the wake of such a state the total number of investments may increase and will be characterized by an abnormally high percentage of investments by informed investors.

We test the theory of heterogeneous information and investment under uncertainty with firm-level data on FDI to Korea during the unusual behavior of the Korean won/US dollar exchange rate at the time of the Asian financial crisis. We identify about 30% of the over 10,000 instances of firm-level FDI data in Korea between 1996 and 2001 as being by experienced

investors, that is as being as second or subsequent FDI to Korea by the investor. In empirical work we examine two periods: 1996:1-1998:10 and 1996:1-2001:12. Both periods capture the period of the Asian financial crisis and the longer period allows for change in capital control. Results on the effect of exchange rate volatility on FDI grouped by investor experience are similar in both samples.

In negative-binomial regressions, we find that the FDI count for investors with paired experience, that is a second or subsequent FDI by a foreign investor with the same host firm, is responsive to changes in exchange rates and exchange rate uncertainty whereas that of FDI count for inexperienced investors is not. The count of FDI that is most sensitive to exchange rates and exchange rate uncertainty is that by investors with paired experience making FDI of large value. In the binomial logit regressions, controlling directly for size of FDI and host firm affiliation, we find that FDI by investors with paired experience is significantly more sensitive to the exchange rate than that of FDI by other investors.

The empirical results bear out the implications of the theory of heterogeneous information and investment under uncertainty presented in this paper that information (indicated by experience) of investors influences how they will respond to the objective data (on exchange rate and volatility in the exchange rate).

References

Abel, Andrew B., Dixit Avinash K., Eberly Janice C. and Robert S. Pindyck (1994). 'Options, the Vale of Capital, and Investment," *Quarterly Journal of Economics*, 111, 753-777.

Barkema, H. and F. Vermeulen (1998). "International expansion through start-up or acquisition: A learning perspective.'' *Academy of Management Journal*, 41: 7-26.

Bertola, Guiseppe, and Ricardo I Caballero (1994). "Irreversibility and Aggregate Investment," *Review of Economic Studies*, 61, 223-246.

Belderbos, R. and L. Sleuwaegen, (1996) "Japanese firms and the decision to invest abroad: Business groups and regional core networks," *Review of Economics and Statistics*, 78 (2), 214-220.

Blonigen, Bruce A. (1997) "Firm-Specific Assets and the Link between Exchange Rates and Foreign Direct Investment," *American Economic Review* 87, 447-65.

Blonigen, Bruce A. (2005) "A review of the Empirical Literature on FDI Determinants," *NBER Working Paper* 11299.

Blonigen, Bruce A., Christopher J. Ellis, and Dietrich Fausten (2005) "Industrial Groupings and Foreign Direct Investment**,**" *Journal of International Economics*, 65, 75-91.

Bloom , Nick, Stephen Bond and John Van Reenen (2007) "Uncertainty and Investment Dynamics," *Review of Economic Studies*, forthcoming.

Borensztein, Eduardo and Jong-Wha Lee (2002) "Financial Crisis and Credit Crunch in Korea: Evidence from Firm Level Data," *Journal of Monetary Economics* 49 853-875.

Campa, Jose Manuel (1993) "Entry by Foreign Firms in the United States under Exchange Rate Uncertainty," *Review of Economics and Statistics* 75-4, 614-622.

Caves, Richard (1971) "International Corporations: The Industrial Economics of Foreign Investment," *Economica*, 38, 1-27.

Chang, Sea Jin and Phillip M. Rosenzweig (2001) "The Choice of Entry Mode in Sequential Foreign Direct Investment," *Strategic Management Journal*, 22, 747-776.

Cushman, David O. (1985) "Real Exchange Rate Risk, Expectations, and the Level of Direct Investment," *Review of Economics and Statistics* 67-2, 297-308.

Davidson, William H. (1980) "The Location of Foreign Direct Investment Activity: Country Characteristics and Experience Effects," *Journal of International Business Studies*, 11, 9-22.

Dewenter, Kathryn (1995) "Do Exchange Rate Changes Drive Foreign Direct Investment?" *Journal of Business*, 68, 405-33.

Dixit, Avinash K, (1989) "Entry and Exit Decisions under Uncertainty," *Journal of Political Economy*, 97, 620-38.

Dixit, Avinash K. and Pindyck, Robert S. (1994) *Investment under Uncertainty*, Princeton, New Jersey: Princeton University Press.

Dunning, J.H. (1988) *Explaining International Production*, London: Harper Collins.

Easley, D. and N. M. Kiefer (1988) "Controlling a Stochastic Process with Unknown Parameters," *Econometrica,* 56, 1045-1064.

Froot, Kenneth A. and Stein, Jeremy (1991) "Exchange Rates and Foreign Direct Investment: An Imperfect Capital Market Approach," *Quarterly Journal of Economics* 106, 1191-1217.

Goldberg, Linda S. and Charles D. Kolstad (1995) "Foreign Direct Investment, Exchange Rate Variability and Demand Uncertainty," *International Economic Review* 36-4, 855-873.

Hausman, Jerry A, B. Hall, and Z. Griliches (1984) "Econometric Models for Count Data with an Application to the Patents-R&D Relationship", *Econometrica*, 52, 909-938.

Head, K., Ries, J., and Swenson, D. (1995) "Agglomeration benefits and location choice: evidence from Japanese manufacturing investments in the United States," *Journal of International Economics*, 38 (3-4), 223-247.

Jovanovic, Boyan (1979) "Job Matching and the Theory of Turnover," *Journal of Political Economy* 87, 972-90.

Kiyota, Kozo and Shujiro Urata (2004) "Exchange Rate, Exchange Rate Volatility and Foreign Direct Investment," *World Economy* 27, 1501-1536.

Klein, Michael W. and Eric Rosengren (1994) "The Real Exchange Rate and Foreign Direct Investment in the United States," *Journal of International Economics* 36, 373-389.

Kogut, Bruce (1983) "Foreign direct investment as a sequential process, " in C. Kindleberger and D. Audretsch (eds.), *The multinational corporation in the 1980s*. Cambridge, MA: MIT Press.

Kogut, Bruce and Chang, Sea Jin (1996) "Platform Investments and Volatile Exchange rates: Direct Investment in the U.S. by Japanese Electronic Companies," *Review of Economics and Statistics*, 78, 221-31.

Lipsey, Robert E. (2000) "Interpreting Developed Countries' Foreign Direct Investment," *NBER Working Paper* 7810.

Lipsey, Robert E. (2001) "Foreign Direct Investment in Three Financial Crises," *NBER Working Paper* 8084.

Markusen, J.R. (2002) *Multinational Firms and the Theory of International Trade*, Cambridge: MIT Press.

McDonald, Robert L. and Daniel Siegel (1986) "The Value of Waiting to Invest," *Quarterly Journal of Economics*, 101, 707-27.

Mody, Ashoka, Assaf Razin, and Efraim Sadka (2002) "The Role of Information in Driving FDI: Theory and Evidence," *NBER Working Paper* 9255.

Prescott, Edward C. and Robert M. Townsend (1980) "Equilibrium Under Uncertainty: Multiagent Statistical Decision Theory," in *Bayesian Analysis in economics and Statistics* edited by Arnold Zellner, 167-194.

Rauch, James E. (1999) "Networks versus Markets in International Trade**,**" *Journal of International Economics*, 48, 7-35.

Rauch, James E. and Vitor Trindade (2003) "Information, International Substitutability, and Globalization," *American Economic Review* 93, 775-91.

Razin, Assaf and Efraim Sadka (2002) "Gains from FDI Inflows with Incomplete Information," *NBER Working Paper* 9008.

Wieland, Volker (2000) "Monetary Policy, Parameter Uncertainty and Optimal Learning," *Journal of Monetary Economics*, 46 (1), 199-228.

Table 1. Size Distribution of FDI in Korea over 1994:11-2001:10

Size of FDI (millions US dollars)	Number of FDI						
	1994:11-1995:10	1995:11-1996:10	1996:11-1997:10	1997:11-1998:10	1998:11-1999:10	1999:11-2000:10	2000:11-2001:10
FDI≥1000	0	0	0	0	1	1	0
1000>FDI≥200	0	0	2	3	6	9	6
200>FDI≥100	0	2	2	8	9	13	6
100>FDI≥10	26	40	57	86	102	113	101
10>FDI≥1	152	182	222	237	235	334	311
1>FDI	533	709	685	823	1045	3539	2309
Total	711	933	968	1157	1398	3009	2733

Size of FDI (millions US dollars)	*Amount of FDI-millions US dollars*						
	1994:11-1995:10	1995:11-1996:10	1996:11-1997:10	1997:11-1998:10	1998:11-1999:10	1999:11-2000:10	2000:11-2001:10
FDI≥1000	0	0	0	0	1,612	1,342	0
1000>FDI≥200	0	0	502	941	1,519	3,122	2,196
200>FDI≥100	0	309	300	1,223	1,106	1,726	777
100>FDI≥10	600	915	1,485	2,179	3,011	3,473	2,664
10>FDI≥1	424	534	653	723	840	1,095	979
1>FDI	128	173	158	165	155	316	277
Total	1152	1,930	3,099	5,231	8,244	11,075	6,894

Source of data: Invest Korea, Korea Trade and Investment Promotion Agency, Ministry of Commerce, Industry & Energy, Seoul, Korea.

Table 2. The Role of Experience in FDI Cases: 1996:1-2001:12 (average size in parentheses)

Host firm type: # FDI	Number of cases of Experience				
	Host firm	Investor	Investor & Host firm	Paired	None
All firms: 10405(3.52)	3180(6.09)	3119(5.95)	2496(6.11)	2418(6.17)	6137(2.29)
Foreign-owned firms: 4099(4.45)	1802(6.53)	1803(7.49)	1595(6.03)	1574(6.03)	2020(2.95)
Unlisted Domestic firms: 6068(2.41)	1240(4.74)	1164(2.65)	795(5.26)	746(5.43)	4025(1.62)
Listed firms (Public firms): 268(14.76)	138(12.46)	152(13.00)	106(13.68)	98(13.95)	92(16.90)

Note: Investor experience - the investor has at least one prior FDI before the one counted (the host firm may or may not have FDI experience). Host firm experience - the host firm has at least one prior FDI before the one counted (the investor may or may not have FDI experience). Investor and host firm experience - both firms have had at least one prior FDI before the one counted (it may or may not have been with each other). Paired experience - the same host/investor pair had at least one prior FDI with one another before the one counted. None - first-time FDI by agents that become an experienced pair and by agents that never have a repeat FDI experience (this is slightly smaller than the number of first time FDI for both investor and host firm). The large average size of FDI to listed firms with no experience is due to two large FDI of \$321 million and \$119 million. The number of FDI by host firm's sub-categories exceeds the total number of FDI by 30, since 30 FDI went to listed foreign owned firms. An unlisted firm is taken as foreign-owned if it bears the same name as the foreign investor.

Source of data: Invest Korea, Korea Trade and Investment Promotion Agency, Ministry of Commerce, Industry & Energy, Seoul, Korea.

Table 3A. Negative Binominal Results: Monthly FDI Count by Investors with Different Experience Levels: 1996:1-1998:10

Parameter	FDI by all Investors (n=2896)			FDI by Investors with no Experience (n=1468)		
	i	*ii*	*iii*	*iv*	*v*	*vi*
Crisis	0.1532[c] (0.0835)			0.0361 (0.0936)		
Lex		0.3709[a] (0.1421)			0.2001 (0.1619)	
$L(sdex)$			0.0643[b] (0.0267)			0.0335 (0.0302)
Dispersion	0.0352[a] (0.0115)	0.0311[a] (0.0105)	0.0312[a] (0.0110)	0.0345[a] (0.0142)	0.0328[a] (0.0140)	0.0333[a] (0.0141)

Parameter	FDI by Investors with paired experience (n=1091)			Large FDI by Investors with paired experience (n=445)		
	vii	*viii*	*ix*	*x*	*xi*	*xii*
Crisis	0.2716[a] (0.0983)			0.4541[a] (0.1351)		
Lex		0.5338[a] (0.1724)			1.0361[a] (0.2154)	
$L(sdex)$			0.0979[a] (0.0320)			0.1855[a] (0.0433)
Dispersion	0.03616[a] (0.0165)	0.0332 (0.0158)	0.0335 (0.0158)	0.0564 (0.0327)	0.0321 (0.0259)	0.0408 (0.0278)

Notes: Investors with paired experience refers to investor and host firm having FDI experience with each other prior to current FDI event. FDI by investors with no experience is first-time FDI by investors. Large FDI is FDI greater than or equal to $1 million. Crisis=index for financial crisis set at 1 over 1997:11-1998:7 and zero otherwise; Lex= log of 3-month moving average of exchange rate (won per dollar) centered on preceding month; Volatility- $L(sdex)$ = the log of the of 3-month moving average of standard deviation of the daily change in the won/dollar exchange rate each month centered on the preceding month; Standard errors are given in parenthesis. Superscripts a, b, and c indicate significance level of at least 99%, 95%, and 90% or above, respectively.

Table 3B. Negative Binominal Results: Monthly FDI Count by Investors with Different Experience Level for Different Measures of Volatility of Exchange Rates: 1996:1-1998:10

Parameter	FDI by all Investors (n=2896)			FDI by Investors with no Experience (n=1468)		
	Volatility = $L(garch)$	Volatility = $V(\exp)$	Volatility = $V(\max)$	Volatility = $L(garch)$	Volatility = $V(\exp)$	Volatility = $V(\max)$
	i	*ii*	*iii*	*iv*	*v*	*vi*
Volatility	0.0578^b (0.0271)	0.0513 (0.0321)	0.0638 (0.0470)	0.0322 (0.0303)	0.0218 (0.0349)	0.0205 (0.0509)
Dispersion	0.0338^a (0.0112)	0.03631^a (0.0118)	0.0373^a (0.0120)	0.0335^a (0.0141)	0.0348^a (0.0144)	0.0352^a (0.0145)

Parameter	FDI by Investors with paired experience (n=1091)			Large FDI by Investors with paired experience (n=445)		
	Volatility = $L(garch)$	Volatility = $V(\exp)$	Volatility = $V(\max)$	Volatility = $L(garch)$	Volatility = $V(\exp)$	Volatility = $V(\max)$
	vii	*viii*	*ix*	*x*	*xi*	*xii*
Volatility	0.0801^a (0.0334)	0.0775^b (0.0334)	0.1038^c (0.0571)	0.1684^a (0.0449)	0.1402^a (0.0558)	0.1770^b (0.0823)
Dispersion	0.0394^b (0.0173)	0.0430^a (0.0180)	0.0442^a (0.0184)	0.0506 (0.0304)	0.0752^b (0.0363)	0.0810^b (0.0379)

Notes: Investors with paired experience refers to investor and host firm having FDI experience with each other prior to current FDI event. FDI by agents with no experience is first-time FDI by agents. Large FDI is FDI greater than or equal to $1 million. Volatility- $L(garch)$ = log of 3-month moving average of monthly exchange rate volatility given by the conditional standard deviation generated by a GARCH process fitted to the exchange rate, centered on preceding month; Volatility is also measured alternatively by $V(\max) = 0.01\max\{ex - 1300, 0\}$ and by $V(\exp) = e^{\{(ex-1300)/200\}}$, where ex is 3-month moving average won/dollar exchange rate. Standard errors are given in parenthesis. Superscripts a, b, and c indicate significance level of at least 99%, 95%, and 90% or above, respectively.

Table 3C. Negative Binominal Results: Monthly FDI Count by Investors with Paired Experience (Large FDI only) and by Investors with No Experience: 1996:1-2001:12

Parameter	Large FDI by Investors with paired experience (n=1041)					
			Volatility = $L(sdex)$	Volatility = $L(garch)$	Volatility = $V(\exp)$	Volatility = $V(\max)$
	vii	*viii*	*ix*	*x*	*xi*	*xii*
Crisis	0.2474[b] (0.1202)					
Lex		0.9343[a] (0.2094)				
Volatility			0.1701[a] (0.0377)	0.1135[a] (0.0370)	0.1703[b] (0.0701)	0.1251[a] (0.0471)
cc		0.0272 (0.0813)	0.1885[b] (0.0747)	0.1844[b] (0.0793)	0.2549[a] (0.0866)	0.2020[b] (0.0809)
Dispersion	0.0559[a] (0.0214)	0.0293[a] (0.0166)	0.0287 (0.0165)	0.0417 (0.0188)	0.0466 (0.0197)	0.0453 (0.0194)

Parameter	FDI by Investors with no Experience (n=6137)					
			Volatility = $L(sdex)$	Volatility = $L(garch)$	Volatility = $V(\exp)$	Volatility = $V(\max)$
	vii	*viii*	*ix*	*x*	*xi*	*xii*
Crisis	-0.7200[a] (0.2039)					
Lex		-0.0103 (0.2416)				
Volatility			-0.0111 (0.0377)	-0.0306 (0.0395)	0.0128 (0.0778)	-0.0090 (0.0514)
cc		1.0476[a] (0.0947)	1.0457[a] (0.0846)	1.0444[a] (0.0842)	1.0508[a] (0.0897)	1.0446[a] (0.0849)
Dispersion	0.3062[a] (0.0507)	0.1124[a] (0.0204)	0.1122[a] (0.0203)	0.1111[a] (0.0202)	0.1124[a] (0.0204)	0.1123[a] (0.0204)

Notes: Investors with paired experience refers to investor and host firm having FDI experience with each other prior to current FDI event. FDI by investors with no experience is first-time FDI by investors. Large FDI is FDI greater than or equal to $1 million. Crisis=index for financial crisis set at 1 over 1997:11-1998:7 and zero otherwise; Lex= log of 3-month moving average of exchange rate (won per dollar) centered on preceding month; Volatility- $L(sdex)$ = the log of the of 3-month moving average of standard deviation of the daily change in the won/dollar exchange rate each month centered on the preceding month; Standard errors are given in parenthesis. Volatility- $L(garch)$ = log of 3-month moving average of monthly exchange rate volatility given by the conditional standard deviation generated by a GARCH process fitted to the exchange rate, centered on preceding month; Volatility is also measured alternatively by $V(\max) = 0.01\max\{ex - 1300,0\}$ and by $V(\exp) = e^{\{(ex-1300)/200\}}$, where ex is 3-month moving average won/dollar exchange rate. cc= index of capital control set at zero prior to 1998:11, and set at 1 after 1998:11. Superscripts a, b, and c indicate significance level of at least 99%, 95%, and 90% or above, respectively.

Table 4A. Binomial Logit Regressions: Likelihood of FDI by Investors with Paired Experience Relative to that by Other Agents: 1996:1-1998:10 & 1996:1-2001:12

Dependent variable 1: FDI by Investors with paired experience.
Dependent variable 2 (the default): All other FDI.

Parameter	1996:1-1998:10 FDI by Investors with paired experience (second and subsequent FDI)			
	i	ii	iii	iv
Lex		0.0130[c] (0.0075)		-0.0091 (0.0131)
$L(sdex)$			0.0471[a] (0.0182)	0.0649[b] (0.0293)
$Lsize$	0.2628[a] (0.0204)	0.2761[a] (0.0219)	0.2790[a] (0.0214)	0.2758[a] (0.0219)
Domestic	-0.8545[a] (0.0762)	-0.9310[a] (0.0882)	-0.9458[a] (0.0842)	-0.9275[a] (0.0883)

Parameter	1996:1-2001:12 FDI by Investors with paired experience (second and subsequent FDI)			
	v	vi	vii	viii
Lex		0.0310[a] (0.0066)		-0.0001 (0.0120)
$L(sdex)$			0.0911[a] (0.0162)	0.0913[a] (0.0293)
cc	-0.4882[a] (0.0419)	-0.6567[a] (0.0549)	-0.6458[a] (0.0500)	-0.6456[a] (0.0550)
$Lsize$	0.3546[a] (0.0128)	0.3668[a] (0.0128)	0.3664[a] (0.0127)	0.3664[a] (0.0128)
Domestic	-0.9856[a] (0.0514)	-1.0661[a] (0.0540)	-1.0604[a] (0.0529)	-1.0603[a] (0.0540)

Notes: Investors with paired experience refers to investor and host firm having FDI experience with each other prior to current FDI event. Lex= log of 3-month moving average of exchange rate (won per dollar) centered on preceding month; Volatility- $L(sdex)$ = the log of the of 3-month moving average of standard deviation of the daily change in the won/dollar exchange rate each month centered on the preceding month; cc= index of capital control set at zero prior to 1998:11, and set at 1 after 1998:11; $Lsize$ = the log of size of individual FDI; *Domestic* =1 if the FDI host is an unlisted domestic firm, and 0 otherwise;. Standard errors are given in parenthesis. Superscripts a, b, and c indicate significance level of at least 99%, 95%, and 90% or above, respectively.

Table 4B. Binomial Logit Regressions: Likelihood of FDI by Investors with Paired Experience Relative to that by Other Agents for Different Measures of Volatility: 1996:1-1998:10 & 1996:1-2001:12

Dependent variable 1: FDI by Investors with paired experience.
Dependent variable 2 (the default): All other FDI.

Parameter	1996:1-1998:10 FDI by Investors with paired experience (second and subsequent FDI)					
	Volatility = $L(garch)$		Volatility = $V(\exp)$		Volatility = $V(\max)$	
	i	ii	iii	iv	v	vi
Lex		-0.0161 (0.0185)		0.0064 (0.0082)		0.0044 (0.0086)
Volatility	0.0303[b] (0.0133)	0.0564[c] (0.0327)	0.1195[a] (0.0453)	0.1050[b] (0.0491)	0.0804[a] (0.0341)	0.0721[b] (0.0341)
Lsize	0.2791[a] (0.0217)	0.2765[a] (0.0219)	0.2718[a] (0.0207)	0.2772[a] (0.0219)	0.2737[a] (0.0219)	0.2771[a] (0.0219)
Domestic	-0.9454[a] (0.0862)	-0.9289[a] (0.0883)	-0.8892[a] (0.0783)	-0.9310[a] (0.0883)	-0.9110[a] (0.0794)	-0.9309[a] (0.0883)

Parameter	1996:1-2001:12 FDI by Investors with paired experience (second and subsequent FDI)					
	Volatility = $L(garch)$		Volatility = $V(\exp)$		Volatility = $V(\max)$	
	vii	viii	ix	x	xi	xii
Lex		-0.0100 (0.0156)		0.0165[b] (0.0078)		0.0239[a] (0.0074)
Volatility	0.0631[a] (0.0115)	0.0788[a] (0.0273)	0.1581[a] (0.0287)	0.1201[a] (0.0340)	0.1828[a] (0.0506)	0.1101[b] (0.0506)
cc	-0.6559[a] (0.0516)	-0.6436[a] (0.0551)	-0.5594[a] (0.0436)	-0.6321[a] (0.0554)	-0.4700[a] (0.0421)	-0.6078[a] (0.0595)
Lsize	0.3677[a] (0.0128)	0.3671[a] (0.0128)	0.3632[a] (0.0127)	0.3676[a] (0.0128)	0.3597[a] (0.0126)	0.3671[a] (0.0128)
Domestic	-1.0659[a] (0.0533)	-1.0602[a] (0.0540)	-1.0336[a] (0.0521)	-1.0644[a] (0.0540)	-1.0157[a] (0.0519)	-1.0657[a] (0.0540)

Notes: Investors with paired experience refers to investor and host firm having FDI experience with each other prior to current FDI event. Lex= log of 3-month moving average of exchange rate (won per dollar) centered on preceding month; Volatility- $L(garch)$ = log of 3-month moving average of monthly exchange rate volatility given by the conditional standard deviation generated by a GARCH process fitted to the exchange rate, centered on preceding month; $V(\max) = 0.01\max\{ex - 1300,0\}$ and by $V(\exp) = e^{\{(ex-1300)/200\}}$, where ex is 3-month moving average won/dollar exchange rate; cc= index of capital control set at zero prior to 1998:11, and set at 1 after 1998:11; *Lsize* = the log of size of individual FDI; *Domestic* =1 if the FDI host is an unlisted domestic firm, and 0 otherwise;. Standard errors are given in parenthesis. Superscripts a, b, and c indicate significance level of at least 99%, 95%, and 90% or above, respectively.