WP/07/79

IMF Working Paper

The Effect of Capital Controls on Foreign Direct Investment Decisions Under Country Risk with Intangible Assets

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INTERNATIONAL MONETARY FUND

 WP/07/79

IMF Working Paper

IMF Institute

The Effect of Capital Controls on Foreign Direct Investment Decisions Under Country Risk with Intangible Assets

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April 2007

Abstract

This paper examines how capital controls affect FDI decisions and how the impact of these restrictive measures varies with different levels of country risk. We construct a model of firms' FDI decisions, broadly in Dunning's "eclectic theory" framework, using "real options" to emphasize economic uncertainty and country risk. Numerical results of the model take the form of "quality statistics" that uncover the underlying dynamics hidden in the aggregate data that is responsible for the low performance of recent empirical studies. We find that increasing levels of capital controls reduce the life-span of FDI investments at each level of country risk and foreign investors' willingness towards risk sharing increases. We reveal a significant interaction between capital control and country risk, resulting in a nonlinear relationship between these and the volatility and volume statistics. We estimate a standard cross-sectional model that provides strong support for our theoretical findings.

JEL Classification Numbers: F21, F23, G15, H87, G18, G38
Keywords: Foreign direct investments, capital controls, decisions under uncertainty
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* This paper was written as part of my PhD Thesis at Melbourne University, Australia and as a Visiting Research collaborator at Princeton University. I would like to thank Savas Dayanik, Avinash Dixit and Victoria Henderson from Princeton University, Andrew Feltenstein and Felix Vardy from the IMF Institute, Paul Kofman and Peter Summers from Melbourne University, Australia for their helpful comments and suggestions.

Contents Page

I. Introduction

Reversing the trend toward extensive capital market liberalization that dominated economic theory in the 1990's, as an aftermath of the Asian capital account crises, a new stream of policy agenda has emerged with an unconcealed protectionist overtone. It resulted in many publications favoring capital controls to restrict short-term, volatile flows ('hot money') and promote long-term flows, particularly, foreign direct investments (FDI). The majority of these studies concentrate on how restrictions on capital movements can improve the stability of a country's total capital inflow through diverting its composition toward long-term capital, that by assumption is considered to maintain superior qualities over short-term investments. Concentration on capital composition ignores that financial markets for different types of capital flows are interrelated, hence taking actions with the aim of controlling short-term capital flows induces an effect on the stability properties of long-term investments as well. Moreover, the effectiveness of capital controls is not straightforward as it highly depends on the imposing country's economic characteristics, particularly, its overall business climate or country risk properties. As such, restrictions on capital movements can also diversly affect the properties of long term flows.

The majority of long-term capital flows consist of foreign direct investments, typically sought and promoted by governments. Hence, it is of overriding importance to understand how the desire to control capital movements alters their qualitative properties. Despite their salient economic policy impact the interactions between restrictions on capital flows and FDI received only limited attention in the literature that is dominated by the short-term aspects of capital controls (Rodrik and Velasco (1999), Montiel and Reinhart (1999)), while the relationship between country risk and capital control is entirely neglected in the theory. The purpose of this paper is to provide a theoretical analysis to address these issues by investigating how capital controls affect FDI decisions and how the impact of these restrictive measures varies with different levels of country risk. It also contributes to the empirical literature by generating a series of testable hypotheses that improves the performance of the prevalent econometric models.

Capital controls are administrative measures initiated by governments to alter the composition or size of foreign investments and also to restrict capital outflow of the economy. According to the IMF, by the end of 1996, 144 of a total of 168 countries had some type of controls to promote direct investment (mainly profit repatriation restrictions), 128 countries controlled transactions in capital market securities, and 112 countries regulated trade in money market instruments Hartwell(2001). Proponents of these restrictive measures argue that they can help to combat volatility of investments flows and prevent contagion by segregating the economy of the rest of the world. Capital controls are perceived to be particularly effective when financial markets are not well developed, as these offer protection against speculators and allow governments to buy time. In this respect they act like a temporary last resort. The so called second-best arguments (Ariyoshi et.al. (2000), Laurence and Cardoso(1998)) also suggest that capital account restrictions can be welfare improving by adjusting for financial market imperfections, especially in the case of asymmetric information. Krugman(1998) and Rogoff(2002) are the most prominent proponents of capital controls. They emphasize the beneficial effects of restrictions as a means to at least temporarily avoid major capital flight in the case of a financial crisis and to divert the composition of capital flows toward long-term investments such as FDI.

Not questioning the validity of these statements there are some issues that we have to consider. Asiedu and Lien(2004) note that capital controls fall into two categories: administrative or direct controls and indirect controls. The former restrict capital movements through outright prohibitions, while the latter exercise market-based control by introducing multiple exchange rate systems and other indirect regulatory measures. According to the above definition, capital controls, especially market-based measures affect all types of capital by indirectly increasing the costs of capital movements and associated transactions. Although, restricting short-term capital might indeed decrease the volume of volatile short term flows, it can reduce the stability of the long-term investments at the same time. Hence the total effect of the barrier is ambiguous. It is true that capital controls can divert the composition of capital towards long-term flows that materializes in a higher FDI/Total Capital Stock share. However, the overall amount of total capital stock (the sum of short and long-term flows) might decrease as a reaction to the restrictive measures that thwart both short and to a lesser extent long-term flows. Therefore, neglecting the effect of capital controls on long term flows, especially FDI, can result in policy mismanagement due to the inconsistency of the attempt to attract long term, favorable foreign direct investment flows and to restrict short term flows at the same time. Furthermore, Asiedu and Lien (ibid.) argue that most developing countries receive very limited amounts of portfolio investment, hence the impact of capital restrictions on private foreign investments is determined predominantly by how controls affect FDI movements.

The prevalent, scarce and predominantly empirical literature that analyzes the effect of capital controls on foreign direct investments is not capable of shedding light on the above matters. The existing studies are inconclusive even about the sign of the impact of restrictions. Some authors find evidence that capital controls deter FDI (Desai et.al.(2004), Mody and Murshid(2002), Ariyoshi et.al.(2000)), while others state that restrictions aiming to decrease short-term flows induce a larger inflow of FDI (Montiel and Reinhart(1999)). In a summary of empirical studies on the effects of capital controls, Eichengreen(2001) found no decisive results in favor or against the assumption that lifting capital controls enhances the overall volume of capital flows. Therefore, to complete the analysis on the nature of capital controls, it is of particular importance to gain insight how these measures alter the behavior of foreign direct investments. By creating a model framework that is able to extract the individual effects of country characteristics and policy measures, we can contribute to the resolution of the inconsistencies in the empirical findings.

The inconsistency of the empirical models of capital control and FDI arises from the complex interactions among microeconomic variables that determine the aggregate capital movements.

According to Ariyoshi et al.(2000) it is very hard to differentiate between the effects of capital controls and other factors in explaining the changes in the underlying variables altogether as the effects are hard to follow up in the aggregated data analyses. The paper tackles this problem by approaching it from the microeconomic level, analyzing how single foreign direct investment decisions alter when controls on capital movements are introduced. By applying a stochastic dynamic decision theoretical model the hidden dynamics behind the aggregate capital flows are revealed, allowing us to make more adequate statements on how these are affected by specific restrictive measures. The model also enables us to investigate the interaction between the changes in the economic environment, e.g. changes in the country risk, and the impact of capital controls. This is an addition to the theoretical literature, as there is no attention devoted to the examination of how the country environment alters the effectiveness of capital controls. Based on the prevailing FDI theories the core determinants of foreign direct investment decisions on exit, entry and ongoing investments are determined taking into consideration the risks attached to entering a particular economy. Then restrictions on capital flows are incorporated, by introducing a capital control tax on capital transfers to examine the effect on the volume and maturity of FDI flows. By using the model simulations to generate hypothetical foreign direct investment paths, simulated statistics are generated for different stability measures that comprise average life-span, volume, volatility and average ownership acquisition rate. The findings of the micro decision model are then translated into a system of hypotheses and an empirical investigation is performed. It is shown that extending the prevalent analyses with the findings on microeconomic decisions we can create a conclusive model on the sign and impact of capital restrictions on FDI.

The paper proceeds as follows. The next section discusses the stochastic dynamic decision theoretical model with capital controls represented as taxes on international transfers. Section three examines the investment decisions and the theoretical effects of capital controls on the major qualitative characteristics of aggregate FDI flows: duration, volatility and volume by applying the numerical simulation of the stochastic decision model. Section four contains an empirical investigation of the stability of FDI flows with respect to country risk and capital control, using the results of the theoretical model, while section five concludes. The Appendix contains the mathematical apparatus for the solution of the model and also describes the numerical solution method used in the paper.

II. The Modeling Framework

A. Theoretical Background

To setup the modeling framework we can take advantage of the prevailing FDI literature. Dunning's *eclectic theory* (Dunning(1980), Dunning(1992), Dunning and Dilyard(1999)) is a natural starting point for this purpose. According to the eclectic paradigm, foreign direct investments are driven by three motivating factors: ownership advantages, location advantages, internalization advantages (OLI). Ownership advantages refer to endogenous, firm-specific characteristics such as unique technology, brand-name, managerial or organizational structure that offset the additional costs of conducting business in a foreign environment that arise from differences in culture, language, customs, legal framework etc. Location advantages are exogenous to the firm comprising differences among prices of the factors of production located in different countries. The diverse spatial distribution of internationally static factors can give rise to the emergence of foreign production. Internalization advantages refer to replacing market transactions by extending internal operation. These imperfections comprise externalities that can take the form of government regulations and controls and information asymmetries. Internalization advantages also arise from the difficulty in contracting firm-specific, knowledge assets. The presence of market imperfections prevent efficient operation internationally through the markets therefore foreign firms 'internalize' markets into their firm through acquiring ownership in the previously marketed transactions.

This idea is investigated further in the *property rights approach* by Grossman and Hart(1986). They stipulate that intangible assets are crucial determinants of the amount of control obtained by foreign investors, since these enable firms to operate efficiently in a foreign environment where domestic firms have various advantages. The more intangible assets are provided by the foreign investors to the operation of the domestic firm, the more reluctant the investor becomes to share information and the more he insists on full control or majority-ownership in order to limit the spillover of the proprietary knowledge. As indicated by the *property rights approach,* ownership matters when a contract is incomplete. The incompleteness of the majority of real life contracts arises from the infinity of contingencies that does not allow to specify all the circumstances of asset usage under different occurrences. Therefore the owner of the asset has the right to decide on its employment in any way not inconsistent with the prior contract, custom or law. If contingent contracts could be established to protect the intangible asset provider (i.e. complete contracting is possible), ownership structure would not matter even if there is information asymmetry between the domestic firm owners and the foreign investor.

As in case of real life investments inputs and the resulting outputs are most of the time unobservable and well-specified contracting mechanisms are not in place, the lack of control can lead to the loss of the intangible knowledge capital of the firm. This type of connection between intangible investments, incomplete contracting and knowledge outflow is of crucial importance in the FDI literature as the use of technological knowledge plays a vital role in these types of investments. Foreign direct investment flows can provide external benefits to their host economies. These benefits correspond to the fact that foreign firms assets contain non-proprietary parts that spill over to the industry and later to the whole economy in they are operating. As Graham and Krugman(1995) argue technology diffusion plays an important role even in advanced economies such as the United States. Spillovers are desirable for host economies but if these become extensive due to unclear laws governing intellectual property rights that create a nontransparent economic environment, they can discourage foreign investment as investors become reluctant to put strategically important processes or technology in the host economy.

The above discussed models provide static explanations for the emergence of foreign direct investments. FDI decisions, however, similarly to other financial investment decisions, are dynamic in their nature as their returns spread out in time. According to Aharoni(1966), the investment process takes place under uncertainty, involves different organizational levels, consumes a long period of time and the decision evolves from many intertemporal bargains and commitments within the organization. Investors have the flexibility to adapt to the changes in the economic environment by revising their earlier decisions. Therefore we cannot assume that foreign direct investors are committed to a certain type of operating strategy forever.

To get a full picture we have to incorporate the elements of the theory of finance into the theoretical framework by determining the factors that effect the timing and duration of investment flows. The most important issue is the dynamic uncertainty involved in foreign operation. The above discussed theories emphasize static uncertainties arising from the unfamiliarity of the foreign operating environment, but neglect the issue of uncertainties arising from the dynamic changes in the economic environment. These give rise to questions of optimal strategic decisions on entry, exit and intensity of operations. Dynamic uncertainties comprise two major factors: operational uncertainty characterizing the business risk involved in similar types of businesses, and country risk that comprises the risks involved in choosing a specific location of operations. The major difference between the two types of risks is that business risks are predictable, while country risk is unpredictable to the investors. As business risk can be more or less treated similarly, independently of the location of the firm, it is not responsible for the emergence and continuity of foreign investments. Country risk, however, constitutes a major factor determining FDI decisions. Moosa(2002) defines it as the ‘exposure to a loss in cross-country transactions, caused by events in a particular country that are, at least to some extent under the control of the government but definitely not under the control of a private enterprise or individual’.

Poole-Robb and Bailey(2002) decompose country risk into political and economic factors. Political factors comprise war, disorder, change in the attitude of domestic consumers, government, changes in the rules and regulations The effects of political risk on the cash flows can vary from outright expropriation to changes in the tax or tariff laws. According to Moosa(2002) the economic factors refer to the 'current and potential state of the economy'. These comprise several indicators like interest rate, inflation or exchange rate, economic growth, fiscal balance, unemployment, the extent of export reliance, the balance of payment etc. The effect of country risk may differ for different businesses. Although the overall risk assessment of a country is the same for all actors in the economy there might be special risks attached to a particular industry or firm. Moosa refers to the example of legislations curtailing foreign ownership in strategic sectors, such as mining. This is evidently a country risk for those firms involved in the sector affected by the legislation but not for any other firms. To incorporate these issues into an assessment method he differentiates between macro and micro country risks, where the former covers the overall risk of a country without taking into consideration specific characteristics of the industry, where the investment takes place, while latter refers to the sensitivity of foreign investors' cash flows to changes in the economic environment thus it comprises country characteristics that are specifically related to the business, where the investor indulges.

The microstructure of managerial decisions is similar to the structure of asset pricing decisions in modern financial theory. *Liquidity theory* as part of the financial microstructure theory explains dynamic changes in ownership through the effects of transaction costs on asset trading patterns. The modern asset pricing theory takes advantage of this idea. According to Glosten and Harris(1988) transaction costs comprise fixed and variable costs, the latter correlated with the volume of transaction, while the former is independent of the size of the trade. Therefore the dynamics of asset trade decisions are determined by the structure of the transaction costs. Duffie et.al.(2000) also maintain that transaction costs comprise usual transaction fees such as brokerage fees and bid-ask spread, but also represent the costs arising from delay and search associated with trade execution. Managerial decisions under uncertainty do not take place regularly as they involve certain transaction costs. These costs reduce management's flexibility of continuous intervention when certain environmental factors change. To save on the transaction costs, managers wait until the uncertain input variables for their decisions reach a certain threshold and adjust their control variables in larger amounts in response. This results in a staggered flow of decisions. Staggered decisions are typical when the magnitude of the decision is significant in terms of its financial impact and when the decision itself is less reversible. Therefore, from the financial point of view, foreign direct investment decisions that involve acquiring significant amount of assets that are not easily disposable, are close to simple asset transactions with transaction costs. Hence to fully understand the dynamics of foreign direct investments the amalgamation of *liquidity theory* into the underlying static theory is a straightforward extension. By capturing the cost characteristics of capital controls we are able to represent them as either direct or indirect taxes on capital transfers. This is similar to the idea used by Black(1974), Stulz(1981) and Campion and Neumann(2003) who model restrictions to international capital movements as taxes that hinder net investment or make it costly to hold risky foreign securities. As they tax foreign asset transactions they can be captured in the variable part of the transaction costs, described by Glosten and Harris(1988) .

Hence by including the results of *liquidity theory* in our theoretical analysis we are able to create a framework that is suited for analyzing the effect of capital controls as well. Capital controls are closely related to *liquidity theory* as they are penalizing capital transfers from the restricted market to another. Hence, foreign direct investors are affected by capital controls through two channels. First, capital controls increase the cost of borrowing in the restrictive economy that increases the cost of capital for affiliates of multinational firms that fund themselves from the local market (see Desai et.al. (2004), Dooley and Isard(1980)). Second, capital controls also entail profit repatriation restrictions that reduce the effective returns for foreign direct investors. Multinational corporations can avoid these by adopting tailored transfer pricing policies, yet this is cumbersome and costly to organize. As they limit the flexibility to all capital owners to withdraw or invest their funds into the economy, capital controls create excess cost for the foreign investors who would ideally like to circumvent them. These costs are very close to the transaction costs described in *liquidity theory*. In the next part of this section we set up a microeconomic model that can be used to analyze the qualitative behavior of FDI flows by merging the findings of the existing static theories with the idea of incorporating financial microstructure theory into the investigation.

B. Basic FDI Problem, Model Assumptions

Consider the decision of an investor to start operations in a foreign market. It is assumed that the investor owns a proprietary *knowledge asset,* K_F, that he is able to take advantage of. According to the *property rights approach* we assume that the knowledge asset is non-contractible. Hence if less than full ownership is obtained, the domestic managers of the firm are able to exploit the foreign knowledge, K_F, by setting up a new competitor company. Domestic firms that operate on the market are similar in but one aspect to the foreign firm. The difference between them and their foreign counterpart is their inferior knowledge base, K_D, that makes their production less efficient. The knowledge base of the foreign firm is expressed as a notional industry knowledge base, K_0, multiplied by an efficiency factor, ξ_0, thus $K_F = K_0\xi_0$. It is assumed for simplicity that knowledge is a static attribute to the firm thus the investors are not able to change its quantity. It is also assumed that the knowledge advantage of foreigners decreases over time, with K_F staying constant, due to the spillovers from the foreign firm to the local competitors. The knowledge base of the domestic firms can be represented as $K_{D_t} = K_0(\xi_0 - \xi_t)$, where ξ_t characterizes the efficiency differential at time t. The speed of the decrement in the knowledge differential depends both on the ability of the local firms to absorb the new technology and on the laws governing property rights that avoid knowledge leakages. We refer to these in the following analysis as transparency/spillover factors and we denote them by κ. In accordance with Grossman and Hart(1986) it is assumed that ownership and control are integrated and the more control/ownership is obtained the more spillovers can be reduced. Therefore, the transparency factor is decreasing in control. As control and ownership are used in the same context, we do not differentiate between the two. We denote control/ownership in our model by b. In accordance with our theory, we assume that the derivative of the transparency factor in terms of ownership is negative: $\frac{d\kappa}{db} < 0$. Assuming a simplistic exponential decay process for the knowledge differentials, the actual amount of efficiency gap, ξ, can be represented as follows:

$$\xi_t = \xi_0 \exp(-\kappa(b)t) \tag{1}$$

with

$$d\xi = -\kappa(b)\xi dt \tag{2}$$

It is worth noting that the properties of the spillover function induces $K_{D_0} = 0$ and $K_{D_\infty} = K_F = K_0\xi_0$.

Investors can enter the domestic market by acquiring control in the form of obtaining b_0 share in the domestic firm's assets, or by creating a venture with a domestic firm by acquiring b_0 ownership share of the investment. Ownership share in the firm refers to the total amount of liabilities, including debt instruments as well. This assumption eliminates the problem that equity investments are 'bolted down'[1]. It is also assumed that firms similar to the domestic firm offer the same gains all over the world. The cost of establishing business in the industry is assumed to be the same everywhere. The only difference between entering the industry in different countries lies in the general economic and financial environment of the economy. This assumption allows us to depart from questions on the possible entry modes and the methods of selecting the appropriate location that is not a matter of interest for the investigation[2].

After the entry decisions are made, the investors enter the operation phase of their investment. By employing the superior knowledge asset, K_F, they can extract extra rents compared to the firms that are engaged in similar business in the domestic market. Hence foreign investors are able to increase the value of their firm/venture above the purchase price. The purchase price, namely, reflects the value of the investment under domestic ownership. The actual amount of value increase is not observable to external parties, so the investors are not interested in selling the firm immediately after entering the market[3]. The target industry is assumed to offer a single production good with a hyperbolic overall demand. As we are not interested in the effect of consumer preferences on corporate decisions at this stage we can simply assume that the demand function has a unit elasticity and takes the following form:

$$P = \frac{\theta}{Q_D} \tag{3}$$

where P is the price of the single good produced, Q_D is the domestic demand and θ is a demand parameter comprising the uncertainties originating from the business environment. In accordance with the financial literature θ is assumed to evolve according to a geometric Brownian motion. Assuming that the $(\Omega, \mathcal{F}, Q_P)$ tuple is a complete probability space with a filtration $(\mathcal{F}_t)$ satisfying the conditions of right continuity and augmentation by Q_P- negligible sets, θ is the solution of the following stochastic differential equation:

$$d\theta = \mu \cdot \theta dt + \sigma\theta dB \tag{4}$$

where μ is the growth rate of the market demand. The variability of firm specific shocks is denoted by σ volatility parameter and it is assumed to be a constant. B is a standard one-dimensional $\mathcal{F}_t-$measurable Brownian motion.

In accordance with the dynamic financial microstructure theory outlined in the previous section it is also assumed that in excess of the inherent business risks there is an external environmental risk, called country risk, attributed to the host economy. Country risk is assumed to be beyond the control of the investor and it determines the feasibility of an FDI project. For the purposes of

1 Hausmann and Fernandez-Arias(2000) argue that foreign investors can decrease their *net* ownership (or their interest) in a firm through acquiring debt by using the firm's assets as collateral. In this case FDI is decreased by the acquired debt amount , which is counted as an outflow in the current account.

2 It is very easy to extend the analysis to incorporate the questions of entry, by introducing competing local markets with varying gains. Hence the assumptions do not restrict the applicability of the modeling framework.

3 This eliminates the agency problems due to the asymmetric information, by assuming that the market pays only the minimum price for the firm.

the model we will use the definition of microeconomic country risk, defined by Moosa(2002) that takes into consideration the particular characteristics of the foreign investor's activities in the host economy. To incorporate the unpredictable changes in the economic environment, country risk is assumed to affect the demand for the goods produced by the firm through a *Poisson* component that is added to the motion of θ in the following way:

$$d\theta = \mu\theta dt + \sigma\theta dB - \eta\theta dq \tag{5}$$

Parameter η represents the severity of a negative change in the economic environment. The smaller the level of η the less severe is the effect of a negative change. A value of 1 would indicate that in case of a negative turn in the business environment foreign direct investors loose all their assets[4]. We denote by dq a Poisson process that governs the occurence of a negative shock to the business environment:

$$dq = \begin{cases} 1 \text{ with probability } pdt \\ 0 \text{ with probability } 1 - pdt \end{cases} \tag{6}$$

where p is the country risk parameter representing the probability of financial distress over the next infinitesimal time period. As discussed earlier country risk is assumed to capture any change in the business environment that is a result of government action. As such it incorporates political risks negatively affecting the business environment in which the firm operates.

The Poisson part of the stochastic demand process is considered to be non-diversifiable, so markets attach a risk premium to it. Therefore, the motion of the demand parameter can be written in the following form using the equivalent martingale measure to incorporate the market price of risk that contains the effect of country risk as well:

$$\begin{aligned} d\theta &= (r - \delta + p\eta)\theta dt + \sigma\theta d\widetilde{B} - \eta\theta dq = \widehat{\mu}\theta dt + \sigma\theta d\widetilde{B} - \eta\theta dq \\ d\widetilde{B} &= \frac{\mu - r - p\eta}{\sigma} dt + dB \end{aligned} \tag{7}$$

where the first term in the second equation is the market price of risk including a Poisson risk dependent component.

Profits of the firm under domestic and foreign ownership are represented by the following Cobb-Douglas type functions:

$$f_F = PK_{Ft}^{\alpha}L_{DFt}^{1-\alpha} - c_L L_{DFt} \tag{8a}$$

$$f_D = PK_{Dt}^{\alpha}L_{DDt}^{1-\alpha} - c_L L_{DDt} \tag{8b}$$

where P is the price of the good and c_L is the cost of the flexible asset, such as labor. Parameter α is the coefficient of the Cobb-Douglas function, the knowledge type asset is represented by K_i labor is denoted by L_{Di}, where $i = F$,D referring to foreign and domestic ownership respectively. It is assumed that firms are price takers on the global level, therefore, we can omit the questions

[4] A prime example could be the risk of expropriation that could lead to a total loss of the investment value. In our investigation we do not concentrate on pre-emptive government strategies, therefore we assume that η is less than 1. Nevertheless, this could be an interesting extension of our model framework.

arising from collusive actions. We also assume that there is a fixed cost of operation, C_M. The instantaneous profit maximization problem of the firms are the following:

$$f_{Ft} = \max_{L_{Dt}} P_t K_{Ft}^{\alpha} L_{Dt}^{1-\alpha} - c_L L_{Dt} - C_M \tag{9}$$

After the maximization the profit function takes the following form (see Appendix **??** for the details of the derivation):

$$f_{Ft} = \frac{\alpha\theta\xi_0}{2\xi_0 - \xi_t} - C_M \tag{10a}$$

$$f_{Dt} = \frac{\alpha\theta(\xi_0 - \xi_t)}{2\xi_0 - \xi_t} - C_M \tag{10b}$$

In our analysis we focus on the foreign investor's decisions and we do not investigate further the behavior of domestic firms. By doing this we simplify the analysis, as we omit the different aspects of bargaining and contracting between the local and foreign management. During the operation phase foreign investors are able to change their control over their acquired assets, by changing their ownership share in the firm. According to the *transaction cost theory*, changing ownership involves transaction costs that are attributed to incomplete contracts. We saw that in practice, quantities of inputs and the corresponding output are not verifiable. Moreover, contractual relationships incorporate agency costs due to the lack of effective incentive mechanisms to eliminate these. These so-called spillover costs arise from the inability of parties to write contracts that circumvent such agency problems. Static theories also suggest that ownership acquisition is costly. It is assumed that foreign operation involves some additional costs apart from the normal costs due to the lack of knowledge about the foreign market and the uncertainty of the investment climate. Increased ownership increases exposure to risk resulting in high-control modes with high returns and risks, and low-control modes (e.g. licences and other contractual agreements) with low risk and returns. Therefore foreign investment can be viewed as a trade-off between control and cost of resource commitment. As actual performance is non-observable, market participants are not equally informed about the true value of the firm. Also due to the asset specificity the circle of potential buyers is very limited. These characteristics will induce costs on investors when buying or selling their assets as they have to find their transaction counterparts.

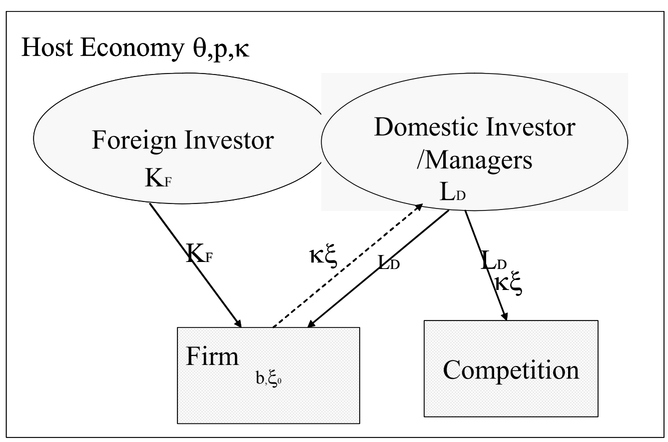
To incorporate these findings of the static and dynamic theories into our model framework we introduce transaction costs to foreign operation that induces foreign investors to change their willingness to obtain control over the operation. We assume that to change the level of ownership investors have to pay a transaction cost, T, that depends on the amount of acquired or sold ownership and the actual value of the firm, denoted by V. Hence $T = T(t, b, b', V_t)$, where b' is the new level of ownership. It is assumed that the higher the absolute value of the change in ownership $|b - b'|$, the higher the level of the transaction cost, $\frac{\Delta T}{\Delta(\Delta b)} > 0$.

According to the *liquidity theory* real life decisions take place irregularly as they are costly to reverse and also costly to implement. As Vollert(2003) argues along these lines, optimal managerial strategy is only to take action when certain significant events occur, therefore, they act only at certain time instances rather then continuously and in between they let the system move uncontrolled. This we represent by the assumption that transaction costs also contain a fixed component. There is a critical size of the imposed change that is needed to compensate for the fixed cost of the transaction. Thus the fixed component reduces managerial flexibility to intervene into the system at each instant[5].

The fixed cost part of the transaction cost depends on the general characteristics of the host country financial markets and the liquidity properties of the firm's assets. The more liquid assets the firm has, the smaller is the amount of the fixed cost involved in the transaction of disposing or acquiring these. Thus we can label the fixed cost component as the liquidity cost of selling and buying assets. Empirical studies show that in case of growing country risk the liquidity of assets decreases. Hence we assume that the fixed part of the transaction cost also depends on the level of country risk (see Duffie et.al.(2000)). A higher level of country risk makes it more difficult to sell the assets of the firm. This imposes an extra cost on the investors as it is becomes more time consuming and costly to find an appropriate buyer. This assumption is incorporated in T by assuming that it contains a fixed cost part thus $T = T(t, b, b', V_t)_{variable} + T(p)_{fix}$. The effects of financial distress, are assumed to have positive impact on the fixed part of the transaction cost, thus $\frac{\Delta T}{\Delta p} > 0$.

The relationship between the domestic and foreign investors is summarized by Figure II.1. The host economy is characterized by the parameters θ, p, κ, that define the operational environment in the target economy in terms of market demand, country risk and transparency.

Figure II.1. Interaction between domestic and foreign investors



Foreign investors apply their superior knowledge assets, K_F, by investing in a domestic "Firm"where they acquire b ownership share of the assets. They use domestic labor L_D and domestic managerial input, in the Firm. Since only the relative capabilities of the domestic and

5 This is somewhat similar to the concept of menu cost of changing prices

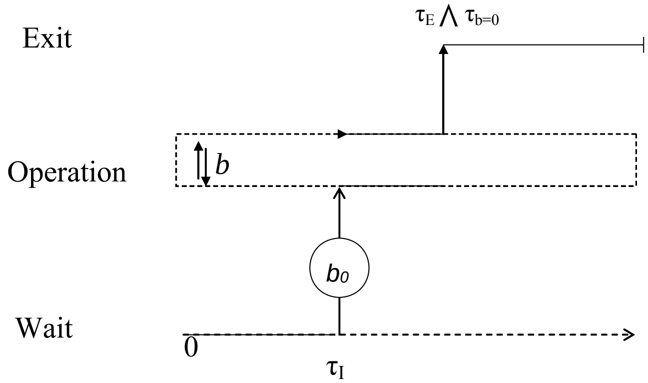
foreign owners matters, we assume that K_D is zero. The initial knowledge differential between the foreign firm and the domestic competition is represented by ξ_0. As the foreign knowledge assets are non-contractible, some proportion of the knowledge advantage,$\kappa\xi$, flows to the domestic investors through the domestic owners of the Firm at each instant, who pass that knowledge over to the local competition. With the newly acquired knowledge the competitive firms' capabilities increase and they are able to predate on the market share of the foreign owned entity. The knowledge flow, and thus the loss in competitive advantage, depends on transparency of the economy that comprises the laws that safeguard intellectual property. The higher the transparency, the lower is the $\kappa\xi$ knowledge spillover. The process stops when knowledge differentials totally disappear together with the comparative advantage of the foreign owned company over its local competition.

Investors also have the option to exit the market at any time by paying an exit fee and 'abandon' their project. According to Boddewyn(1983) there are two major causes of disinvestment in a firm: mistakes in pre-internationalization decisions and activities, and changes in the host market conditions. The first group of exit triggers usually apply in the case of firms that are inexperienced in international markets. Poor decisions may also be the outcome if the firm does not know how to collect sufficient information about the foreign market or it does not have resources for acquiring or analyzing the information. Unfavorable changes in the host country's economic environment are, however, the most decisive determinants of divestments and export withdrawals. As Boddewyn claims divestments are in very few cases strategic decisions, for they are the responses of environmental stimuli that were not anticipated. Divestment decisions differ from decisions under normal operation, as time pressure in case of divestments is likely to hasten and simplify the decisions. Due to these facts there is hardly an example of firms establishing clear criteria for divestment. We can argue that the exit decision of a firm is determined by whether its continuation value is larger than the cost of exit. In terms of foreign divestment, Boddewyn claims that discrepancies are hard to detect due to distance, psychological detachment and the more negative perception of foreign risk.

Hence barriers to exit for the foreign investor are considered to be lower than in case of domestic divestment decisions. Due to the relative indeterminacy of divestments to investment decisions, it is difficult to establish a set modeling rule for the exit decision of firms. We set a boundary condition stating that at any time, the foreign investor can decide to leave the country and abandon their investments if the expected flow of proceeds of the project are less than the fixed, liquidity cost of the project that is represented by C_E. This induces foreign firms to exercise their abandonment option over selling the firm.

Incorporating the opportunity for abandonment we can describe the FDI decision process as a three stage problem that is stylized in Figure II.2..

Figure II.2. Graphical representation of the decision process



The optional time of the entry is represented by τ_I, b_0 is the initial ownership and $\tau_E \wedge \tau_{b=0}$ is the first time the investor chooses to exit or to decrease its ownership share to zero. As we can see investors face three distinct decisions. The solid lines in Figure II.2. represent the irreversible decisions, while the dotted lines refer to reversible switches. As we can see the "Wait" stage of the decision model comprises a voluntary switch at τ_I, where an irreversible initial b_0 ownership acquisition is made. This leads to the second stage of the foreign direct investment decision problem.

The "Operation" stage consists of partially reversible decisions, as foreign investors have the ability to adjust their ownership share any time by paying a transaction cost. Partial reversibility in this case arises from the fact that any transaction involves a fixed cost. The right end of the box and the lines represent the latest possible exit time, while the left end denotes the earliest possible entry time.

The "Exit" stage represents the optional abandonment phase of the decision. Foreign investors first decide on the entry time, together with the initial ownership share they acquire in the firm. This decision resembles very much a simple American call option, with flexible exercise price. Second, investors decide on the operation of the firm by increasing/decreasing their ownership depending on how much risk sharing they desire with the local management. The foreign investor's objective is assumed to be the maximization of the dividend stream, bf_{Ft}, during his investment period. This phase can be described as a compound option of several call and put options on the firm's assets. Finally, investors also have the flexibility to abandon their operation, and simply withdraw from the economy at any point of time in the operation phase. This decision is thus equivalent to an American put option with an exercise price of the exit cost, C_E.

C. Representing FDI Decisions as an Impulse-Control Model

Our foreign direct investment decision model, described in the previous section can be represented as a stochastic impulse-control model. Generally, impulse-control models are used to describe investment decisions in an uncertain environment, where the decisions are at least partially irreversible, and managerial decisions are discrete due to a fixed cost they occur with each intervention. In the case of our model obtaining more ownership bears costs that have a fixed positive part. This induces irreversibility in the decision process, validating the use of an impulse-control model. This approach is capable also to handle the timing issues of entry and exit that we described earlier. In the following we formulate our foreign direct investment model by applying the impulse-control modeling framework.

The entry problem is described as the 'Wait' stage in Figure II.2., investors decide when to enter the domestic market and they determine the initial control would like to take over in the investment. They choose their optimal entry control from the following set $\mathcal{Z}^e = [b_{\min}, b_{\max}] = [0,1]$. In the operation phase the investors are able to decrease or increase the level of ownership in the same range $\mathcal{Z}^e = [b_{\min}, b_{\max}] = [0,1]$. During the operation phase a decision to operate versus abandonment is made at each instant. Investors corresponding choice set can be described by $\mathcal{Z}^E = \{0,1\}$.This is a binary choice set with 0 representing the choice of operation, while 1 the decision of abandonment, the 'Exit' phase. $\mathcal{Z}^e$ and $\mathcal{Z}^E$constitute foreign investor's *action space*[6], in the entry-operation and exit phase, respectively. Let us denote by Z_t^e, Z_t^a and Z_t^E the decision variables representing entry, operation and exit at time t, respectively. Hence $Z_t^e \in \{b_0\} =: \mathcal{Z}^e \subseteq [0,1]$, $Z_t^a \in \{b\} =: \mathcal{Z}^e \subseteq [0,1]$, while $Z_t^E \in \{e\} =: \mathcal{Z}^E \in \{0,1\}$.

The firm's operating business environment is described by the stochastic demand process, θ, and the deterministic ξ process. In the entry period ξ is fixed at ξ_0 by the assumption that knowledge spillovers only occur after entering the market. Let us denote the vector (θ,ξ_0) by U_t^e and (θ,ξ) by U_t^a. By their definition U_t^a and U_t^e are Ito diffusion processes. The state of the whole system at time t in the operation and entry phase can be represented by the following stochastic process:

$$X_t^e = \begin{bmatrix} t \\ U_t^e \\ Z_t^e \end{bmatrix} \in \mathbb{R} \times \mathcal{Z}^e, \ s \le t < \tau_I \tag{11a}$$

$$X_t^a = \begin{bmatrix} t \\ U_t^a \\ Z_t^a \end{bmatrix} \in \mathbb{R}^2 \times \mathcal{Z}^e, \tau_I \le t < \tau_E \wedge \tau_{b=0} \tag{11b}$$

$$X_t^E = \begin{bmatrix} t \\ U_t^a \\ Z_t^E \end{bmatrix} \in \mathbb{R}^2 \times \mathcal{Z}^E, \tau_I \le t < \infty \tag{11c}$$

[6] The mathematical formulation of the model follows closely Vollert(2003), Chapter 3. and Oksendal(2000).

with entry and exit times τ_I and τ_E, respectively and initial values defined by $X_0^e = x^e = (s, u^e, z^e)$, $X^a_{\tau_I} = x^a = (s, u^a, z^a)$ and $X^a_{\tau_I} = x^a = (s, u^a, z^E)$. By the construction of θ we ensured that it satisfies the *Lipschitz and growth conditions* with the corresponding *impulse control strategies* defined as $w^e = \{(t_I, \zeta^e)\}$, $w^a = \left\{\left(t_k^a, \zeta_k^a \cup \zeta_k^E\right); k \in \mathbb{N}\right\}$ and $w^E = \{(t_E, \zeta^E)\}$. This system consist of a sequence of finite stopping times $\tau_I \in [0, \infty)$, $t_k^a \in [\tau_I, \tau_E \wedge \tau_{b=0}]$ and $t^E \in [\tau_I, \infty]$. The corresponding actions/ impulses of ownership acquisition and disposal are $\zeta^e = b_0 \in \mathcal{Z}^a$, $\zeta_k^a = b_{t_k} = b_k \in \mathcal{Z}^a$ and $\zeta_k^E = e = e_k \in \mathcal{Z}^E$. When the investor decides to enter the domestic market at time τ_I she obtains an ownership share of b_0. In the operation phase that follows τ_I and lasts until τ_E investors have the choice to change control over their investment at every t_k instant time instant by choosing a new level of ownership, ζ_k^a. They can also decide to abandon the project altogether by changing e to 1 through taking action ζ_k^E. Additionally, at stopping times τ_I we switch from the entry regime to operation, and at τ_E we switch from the operation regime to abandonment (exit). The associated starting value at τ_I is $z^a = b_0$ and the abandonment value at τ_E is zero in accordance with our model assumptions.

Let $\mathcal{W}$ denote the set of all admissible combined control strategies, consisting of w^e, w^a and finite stopping times τ_I and τ_E. This can be written in the following form:

$$w := (\tau_I, t_1^a, t_2^a, ..., t_k^a, \tau_E; b_0, Z^a_{\tau_I} = b_0, \zeta_1^a, \zeta_2^a, ...\zeta_k^a, 0) \in \mathcal{W}^e \cup \mathcal{W}^a \cup \mathcal{W}^E \tag{12}$$

where $k := \sup\left\{j \in \mathbb{N}; \tau_I < t_j^a < \tau_E\right\} < \infty$ finite number.

The expected cash flows of the foreign investor can be represented by the following equation when the impulse control strategy w is applied:

$$V^w(x) = V(t, u, b_0) = \mathbb{E}^x\left[-e^{-\rho\tau_I}((T(\tau_I, u_{\tau_I}, b_{\tau_I}, 0)) + V_{\tau_I})\right] \tag{13a}$$

$$V_{\tau_I}(t, u, b_0) = \int_{\tau_I}^{\tau_E \wedge \tau_{b=0}} \left[e^{-\rho t} b_t f_F(t, u_t, b_t) - C_M\right] dt - \tag{13b}$$

$$- \sum_{i:\tau_I \le t_i \le \tau_E} e^{-\rho t_i} T(t_i, u_{t_i}, b_{i-1,} b_i, V_{t_i}) - e^{-\rho\tau_E} C_E$$

where V^w is the value of the foreign direct investments project and ρ is the subjective discount factor that is equal to r in our case as we assume perfect spanning[7].

The first part of Equation (13a) describes the entry decision. It states that by paying the initial investment cost $T(\tau_I, u_{\tau_I}, b_{\tau_I}, 0, V_{\tau_I})$ investors get the opportunity to invest in a project with an expected value of V_{τ_I}[8].Equation (13b) represents the second part of the value function. It describes the continuous cash flow stream arising from foreign operation when foreign investors are able to

[7] Perfect spanning of the underlying uncertain variables is a very strong assumption. In real life real option models it almost never holds, and needs careful investigation. For our modeling purposes, however, it is convenient to use that assumption.

[8] The transaction cost function or *switching cost* function needs to satisfy the following conditions to ensure meaningful results (see Vollert (ibid.pp64-65)) :

(i)$T(s, x, \zeta, V_{\tau_I}) > 0 \; \forall x \in \mathbb{R}^3 \times \mathcal{Z}^a$ and all $\zeta \neq z$

change ownership at discrete times by paying the corresponding transaction cost. The expression under the summation mark denotes the sum of the discontinuous transaction payments that management has to make when they decide to change their control over the operation. The second part of the value function contains the property that foreign investors have a choice to abandon their project by paying C_E abandonment price. For the exit to be meaningful the abandonment cost has to be smaller than the fixed part of the transaction cost.

The FDI decision problem can be represented as a continuous time stochastic dynamic optimal stopping problem with impulse control w. The general impulse-control problem of the foreign direct investor is for all $x = (s, u, z)$ the following expression needs to hold:

$$\widetilde{\phi}^a(x) = \sup_{w^e \cup w^a \cup w^E \in W} V^w(x) \tag{14}$$

by finding an optimal impulse control $\widetilde{w} \in \mathcal{W}$ such that

$$\widetilde{\phi}^a(x) = V^{\widetilde{w}}(x) \tag{15}$$

To motivate the solution to the problem it is worth to write out the value function in its extended form:

$$\begin{aligned} \widetilde{\phi}^a(x) &= \\ &= \sup V^w(x) = V^E(t, u, b_0) = \sup_{w^e \cup w^a \cup w^E} \mathbb{E}^x \Big[-e^{-\rho\tau_I}((T(\tau_I, u_{\tau_I}, b_{\tau_I}, V_{\tau_I}))) \\ &\quad + \int_{\tau_I}^{\tau_E \wedge \tau_{b=0}} \left[e^{-\rho t}(b_t f_F(t, u_t, b_t) - C_M)\right] dt - \sum_{i:\tau_I \le t_i \le \tau_E} e^{-\rho t_i} T(t_i, u_{t_i}, b_{i-1,} b_i, V_{t_i}) \\ &\quad - e^{-\rho\tau_E} C_E | \mathcal{F}_s \Big] \end{aligned} \tag{16}$$

Applying the definition of V_{τ_I} and noting that the combined exit operation problem is $\mathcal{F}_{\tau_I}$ measurable, we get the following complex problem:

$$\begin{aligned} \widetilde{\phi}^a(x) &= \sup V^w(x) = V^E(t, u, b_0) = \\ &= \sup_{w^e \cup w^a \cup w^E} \mathbb{E}^{x^e} \Big[-e^{-\rho\tau_I} T(\tau_I, u_{\tau_I}, b_{\tau_I}, V_{\tau_I}(\tau_I, u_t^a, b_0)) \\ &\quad + \sup_{w^a \cup w^E} \mathbb{E}^{x^a} \left[V_{\tau_I}(\tau_I, u_t^a, b_0) | \mathcal{F}_{\tau_I}\right] | \mathcal{F}_s \Big] \end{aligned} \tag{17}$$

As we can see from Equation (13a) the problem can be simplified, by noticing that the operation and exit problem is $\mathcal{F}_{\tau_I}$ measurable. This enables us to split it up into two impulse-control problems with optimal stopping that enables us to use a two stage optimization method. Let us

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(ii)$(s, u, z) \to T(s, u, z, \zeta, V_{\tau_I})$ is continuous for all $\zeta \neq z$

(iii)$T(s, u, z, \zeta_2, V_{\tau_I}) \le T(s, u, z, \zeta_1, V_{\tau_I}) + T(s, u, \zeta_1, \zeta_2, V_{\tau_I})$ if $z \neq \zeta_1$, $z \neq \zeta_2$

The above conditions imply that T has to have a positive fixed cost component and it is right continuous.

define V^A by the following equation:

$$V^A := \sup_{w^a \cup w^E} \mathbb{E}^{x^a}\left[V_{\tau_I}(\tau_I, u_t^a, b_0)|\mathcal{F}_{\tau_I}\right] \tag{18}$$

Then we can write out the original model in Equation (17) into two well defined parts:

$$\begin{aligned} \widetilde{\phi}^a(x) &= \sup V^w(x) = V^E(t, u^e, b_0) = \\ &= \underbrace{\left\{\sup_{w^e} \mathbb{E}^{x^e} - e^{-\rho\tau_I} T(\tau_I, u^e, b_0, V^A)\right\}}_{1.Entry} + \underbrace{\left\{V^A\right\}}_{2.Operation} \end{aligned} \tag{19}$$

We can obtain a solution for $\widetilde{\phi}^a(x)$ recursively by solving first for V^A and then for V^E. The Appendix deals with the mathematical solution method of these types of problems.

Capital Controls (changing c_2)

Capital controls are imposed to limit the volatility and increase the maturity- thus increase the overall stability- of capital flows. Germane to this idea, by restricting capital movements policy makers attempt to change their country's foreign capital composition to FDI that is argued to be less prone to detrimental changes in the economy. Although these measures might be successful in tilting foreign capital inflows towards foreign direct investments they also can alter their qualitative properties. Using the theoretical model developed in the previous section we are able to create measures for stability of FDI flows. Capital controls are assumed to penalize capital transfers from the restricted market to another. As they restrict the flexibility to all capital owners to withdraw or invest their funds into the economy they create excess cost for the foreign investors who would like to circumvent them.

In accordance with the findings of liquidity theory, in the following analysis we employ the assumption that capital controls can be represented as a tax imposed on transactions related to capital movements to and from the host economy. As such, they increase the variable part of the transaction cost, T. Any increase in the input parameter, c_2, can be associated with an increase in the severity of the capital control. This allows us to write the marginal cost of increasing ownership after the imposition of capital controls in the following form:

$$c_{2\gamma} = c_2(1+\gamma) \tag{20}$$

where γ reflects the tax imposed on foreign transactions.

III. Numerical Simulation of the FDI Model

A. Parameters and Numercial Analysis

In order to find numerical solutions of the model we need to introduce specific functions and assign values for the particular parameters. Let the spillover function be given by:

$$\kappa(b) = k + \Lambda(1-b) \tag{21}$$

This expression satisfies our assumption of the spillover function to be decreasing in b the ownership share variable, where $0 \leq b \leq 1$. The constant Λ describes the transparency properties of the economy. The more transparent the economy, the smaller is Λ, expressing less need for increased ownership to retain control over the proprietary knowledge asset. For the numerical solutions to be meaningful, we included a fixed parameter, k in the analysis as well.

In accordance with its theoretical properties, the transaction cost function is assumed to take the following form:

$$T(t_i, \theta_{t_i}, \xi_i, b_{i-1,}b_i, V_i^A, p) = \max(0, V^A(i, \theta_i, \xi_i, b_i)) \left| b_i - b_{i-1} \right| c_2 + c_3 p + c \tag{22}$$

The first part of Equation (22) describes the variable cost part of transactions. This part depends on the size of the ownership acquisition: $\max(0, V^A(i, \theta_i, \xi_i, b_i)) \left| b_i - b_{i-1} \right| c_2$. It is assumed that transaction costs are only paid when the value of the assets is larger than zero. In case the value is negative investors only pay the fixed transaction cost to find a new owner for the project, giving away the firm for free. The variable cost part of transaction is assumed to be linear in the marginal cost c_2. It is also assumed that c_2 is less than one, thus the transaction costs do not exceed the value of the sold assets. The second part of Equation (22) represents the fixed cost part of the ownership acquisition/disposal, where c_3 is an arbitrary constant expressing an increasing pattern in country risk. We also included a small, country risk independent part, c, in the transaction cost that represents the general liquidity characteristics of the firm's assets. The inclusion of c into the equation is a necessary addition as if the fixed cost part approaches zero the numerical solution of the equation does not converge to a limit.

To ensure that the exit boundary is reached with positive probability we set C_E to be smaller than the minimum of the fixed part of the transaction cost and the fixed cost of operation, C_M. Hence our choice for the parameter will be $C_E = \min\left(\frac{c_3 p + c}{2}, \frac{C_M}{2}\right)$.

The constants of the model are arbitrarily chosen to be equal to: $k = 0.4$, $\eta = 0.4$, $c_2 = 0.2$, $c_3 = 1.5$,$c = 0.005$,$C_M = 0.3$, $\sigma = 0.6$, $r = 0.11$, $\delta = 0.06$, $\alpha = 0.4$, $\Lambda = 2$,$p = 0.05$. The choice of r^9 is close to the long term average market return calculated by Ibbotson(2003) [10] for large cap stocks in the US S&P index, with $\delta = 6\%$ representing the stock market premium for this portfolio. Parameter α coincides with the estimates for the US economy and also with several developing economies (see Albuquerque(2003)).

The grid for the explicit finite difference method is defined by the following parameters: $\Delta\xi = 0.04$, $\xi_0 = 10$, $\theta_{\min} = \frac{1}{e^5}$, $\theta_{\max} = e^{15}$, $\theta_0 = e^2$, $\Delta\theta = \sigma\sqrt{3\Delta\xi}$, $\Delta b = 0.1$. The condition for $\Delta\theta$ is derived to satisfy the stability conditions in Equation (B-43)[11]. The grid dimensions are a crucial part of the analysis, as they determine the numerical accuracy of the finite difference method. We performed the analysis with different sets of parameters to ensure the stability of the system.

Table III.1. Summary of parameter values

Parameter	Description	Value
c_2	marginal transaction cost	0.2*
c_3	marginal transaction cost of country risk	1.5
c	fixed transaction cost	0.005
C_M	fixed transaction cost	0.3
k	fixed transparency parameter	0.4
Λ	marginal transparency parameter of ownership	2*
η	Percentage loss due to financial crisis	0.4
σ	Volatility of the demand process	0.6
r	Expected market return on equity	0.11
δ	Market risk premium	0.06
α	Technology parameter	0.4
p	Country risk parameter/ probability of Poisson event occurence	0.05*

* These values are the basis for our calculations for the different scenarios. In the sensitivity analysis performed in the next chapter, we simulate our model for a range of values for these parameters. The rest of the variables remain the same in those cases.

Before analyzing the qualitative properties of FDI, it is worth taking a look at how the various parameters impact the model's results. We start the analysis with the base case parameters. An increase in the discount rate r decreases the future value of the profit stream to the foreign investor. That makes investors less prepared to stay longer and also decreases the value of the investment. The increase in the variance of the demand process, σ, leads to a larger FDI volume and longer

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9 It is very important to note that r is not the risk free rate, but the required rate of return on the project, containing a risk adjustment factor δ. The risk free rate, r_f , is therefore $r_f = r - \delta$.

10 Ibbotson calculates realized returns for different sized companies. As FDI investments are usually large cap companies, we took their estmated values for our simulations. Ibbotson estimated their CAPM betas from monthly portfolio total returns in excess of the 30-day U.S. Treasury bill total return versus the S&P 500 total returns in excess of the 30-day U.S. Treasury bill, January 1926-December 2002. Historical riskless rate is measured by the 77-year arithmetic mean income return component of 20-year government bonds. The Estimated return in excess of riskless rate, δ, calculated in the context of the CAPM by multiplying the equity risk premium by beta. The equity risk premium is estimated by the arithmetic mean total return of the S&P 500 minus the arithmetic mean income return component of 20-year government bonds from 1926-2002.The actual numbers are: r=11.25%, $\delta = 6.34\%$

11 Chosing this spacing allows for the most robust numerical solution; see Hull and White(1987) for further detail.

duration of investments. Higher volatility increases the chances of encountering very high demand values, while the opportunity of loss is limited from below by zero[12]. Increased volatility causes higher trigger values of changes in ownership because the risk represented in the Wiener process is assumed to be market priced. Higher overall growth in the industry demand $\widehat{\mu}$, leads to higher trend-growth of future cash inflows. That, in turn, will lead to an increase in FDI. The parameter α has an effect on the profit stream of the firm. The more knowledge asset specific the production is, the more benefits can be created through the intangible foreign investment. This leads to a greater volume of FDI with a longer duration.

In the following sections we analyze in detail the changes in these environmental parameters on the qualitative measures of FDI. First we need to generate measures that can be used to describe the behavior of FDI. We would like to be able to assess the empirical studies on FDI quality. The majority of these rely on the assessment of the FDI distribution among countries. Therefore, we need to derive measures that can be used to describe the distribution of FDI. The natural candidates are measures describing the volatility, maturity/duration and volume of the FDI projects.

Our model provides us with estimations for the exit and entry times that allows us to create a duration measure (DUR) defined as the difference between the two: $DUR = (\tau_E \wedge \tau_{b=0}) - \tau_I$. Thus duration quantifies the elapsed time between the first entry time,τ_I, and the minimum of the abandonment time, τ_E, and the time when the investors sell off their assets, at time period $\tau_{b=0}$.

The volume measure for the foreign direct investment is derived from the numerical solution of the value function in the following manner: $\Delta\text{FDI}_i = \iota\Delta V_t^A$, $\iota = \begin{cases} 1, \ b' \neq b \\ 0, \ b' = b \end{cases}$, $i = \tau_i ... \tau_E \wedge \tau_{b=0}$. The initial value of FDI investment equals the value function solution of the entry problem: $FDI_0 = V^E(t,b_0,\xi_0,\theta_I)$. As sample volatility measure we can use volatility of the logaritmic change of the FDI path: $\Delta\,\text{lnFDI}_t$. Therefore $\sigma_{FDI} = \frac{\sum_i (\Delta \ln FDI_t - \overline{\Delta \ln FDI_t})^2}{n-1}$, where n is the number of discrete time periods between τ_i and $\tau_E \wedge \tau_{b=0}$.

To analyze the effect of our core environmental variables, we perform a sensitivity analysis on each of these. We simulate our model by taking advantage of the Monte Carlo method. We generate the jump-diffusion demand trajectory in the underlying model for $N = 5000$ times over a 10 year period. We assume that the initial knowledge differential ξ_0 disappears at the end of the tenth year. Based on the sample paths we create the optimal threshold levels for exit and entry. We determine the optimal ownership changes and switch boundaries for different levels of country risk, p, capital control, γ, and transparency factor, Λ, values. We generate the actual amount of foreign direct investment flows for each trajectory to arrive at the underlying distribution of the FDI process itself. We calculate the overall levels of the quality measures as averages of the statistics across the simulation paths. We adjust the volatility measure to a life-period volatility figure by multiplying each volatility number with the square root of the average life span of the FDI project (Adjusted

[12] This is in line with standard option pricing theory. See for example Hull and White(1987) for further detail.

FDI Volatility $= \sigma\sqrt{DUR_{FDIi}},\ i \in N$). The following sections summarize the results of the model simulations.

B. Capital Controls and Country Risk

Table III.2. reports the average lifespan values of the FDI projects with varying country risk and capital controls, when simulating the model. The measure for $\Delta\gamma$ represents 10%-40% increase in the value of the marginal transaction cost, $c_{2.}$

Table III.2. Average Duration of FDI Projects in terms of country risk and severity of capital control, N=5000

p \ $\Delta\gamma$	0	0.1	0.2	0.3	0.4
0	6.59	6.57	6.54	6.50	6.47
0.01	5.46	5.42	5.37	5.32	5.28
0.02	4.40	4.35	4.30	4.25	4.22
0.03	3.55	3.51	3.47	3.43	3.39
0.04	2.96	2.93	2.90	2.87	2.85
0.05	2.48	2.46	2.43	2.41	2.39
0.07	1.92	1.90	1.88	1.86	1.85

The maturity of FDI investments decreases when barriers to capital controls increase for each level of country risk. This shows that strict capital control measures decrease the flexibility of the managers in deciding on the allocation of their investment proceeds. As a result, foreign investors choose to reduce their operation in the market. The marginal effect of country risk on duration is also negative for every level of capital control. Comparing the effects of capital controls at different levels of country risk shows that countries with higher risk face a larger decrement in the average project lifespan of their net FDIs. The negative impact rises with country risk, therefore, introducing capital controls in riskier economies induces a sharper loss in terms of the duration of the FDI projects.

Another useful qualitative measure, derived from the model simulations is the percentage rate of cases when investors choose not to enter the market at all. Consistently with the analysis on the effects of country risk, Table III.3. shows that the actual entry rate decreases in p. We assumed that market risk is not diversifiable, thus there is a risk premium added to the required rates of returns on the investments. Hence the inactive project's value increases in p that creates an incentive for foreign investors to wait. As the fixed cost of entry also increases in the levels of country risk, this will have a negative effect on the entry times as well.

The increased marginal cost of changing ownership, c_2, has a negative effect on the value of the FDI project, as it decreases managerial flexibility to freely adjust ownership in response to changes in demand or country environment. In this case the value of the "wait and see" option becomes higher than the actual value in operation, which will deter entry. Therefore, we observe a

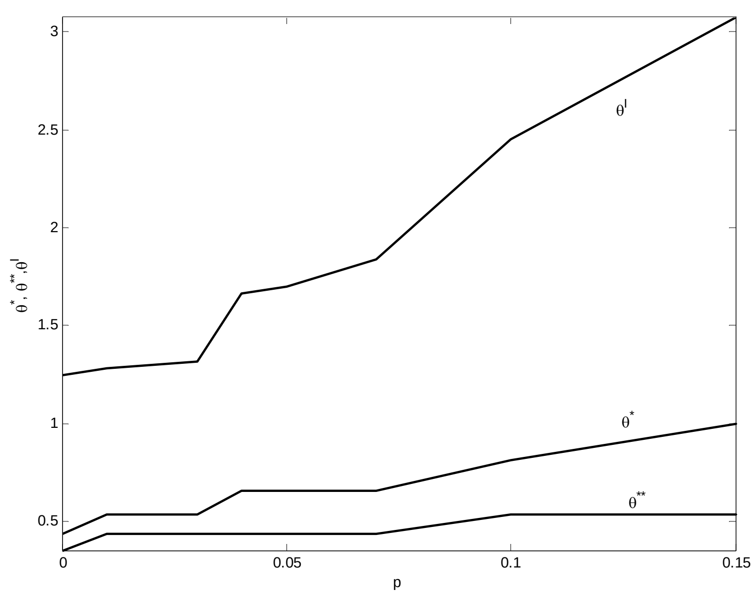
Table III.3. No Entry Ratio in terms of country risk and severity of capital control, N=5000

p $\Delta\gamma$	0	0.1	0.2	0.3	0.4
0	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
0.01	0.34 %	0.34 %	0.34 %	0.34 %	0.34 %
0.02	1.06 %	1.06 %	1.06 %	1.06 %	1.44 %
0.03	1.60 %	1.60 %	2.06 %	2.06 %	2.06 %
0.04	3.12 %	3.12 %	3.12 %	3.12 %	3.12 %
0.05	3.94 %	3.94 %	3.94 %	4.36 %	4.36 %
0.07	6.26 %	6.86 %	6.86 %	6.86 %	7.06 %

decreasing entry rate of foreign investors that is similar to the effect of country risk.

The impact of capital controls, however, is smaller than the country risk effect as country risk alters FDI through more channels. Hence, to understand the effect of capital controls on volatility at varying levels of country risk it is worth to take a look at the impact of country risk separately. We simulated our foreign direct investment model at increasing probability of financial distress, p. The effect of country risk in our model is twofold. On the one hand, it determines the demand trajectory of the underlying economy, while on the other hand it affects the general business environment, by increasing the fixed cost, c_3, of capital acquisitions. Figure III.3. depicts the important triggers resulting from the simulation.

Figure III.3. Trigger values in terms of country risk, N=5000



As we can see from Figure III.3. the trigger values to entry and switch are increasing in country risk. The gap between the switch triggers also increases. These changes lead to a complex resultant effect of country risk. The increasing entry trigger reduces the duration of the FDI project. The gap between the switch triggers determines the frequency of the interventions: in low risk economies there is a relatively high frequency in the occurrence of interventions; in high risk economies there is a relatively low frequency in the occurrence of interventions, ceteris paribus. The trigger values, however, are not sufficient predictors of the FDI properties. Country risk, namely, changes the demand trajectory resulting in a more frequent downward adjustment of the underlying demand parameter. Therefore, in high risk economies the high likelihood of downward adjustment can result in a higher frequency adjustment than in low risk economies. Indeed the average frequency of adjustment increased from 2 to 3 instances in our simulations.

Moreover, as the probability of financial distress increases, the overall value of the FDI investment decreases. The diminishing value of the investment increases the trigger value of θ for exit, as investors are not able to hedge themselves against the unpredictable, negative Poisson occurrences[13]. The higher probability of detrimental effects induces a higher market risk premium with a larger θ trigger value that causes a deferred entry time as well (see Dixit and Pindyck(1994)). This shortens the overall lifespan of the FDI project, leading to a more volatile outcome. On the other hand the fixed cost of ownership acquisition also increases in p, resulting in less frequent trade in the real asset markets. Hence the increase in the fixed cost of ownership changes, leads to a more sluggish change in the ownership structure. This leads to a less volatile FDI flow. The outcome of the opposite effects will determine the actual characteristics of the FDI investment in terms of variable country risk.

As a result of the complex liquidity-volume effect of the triggers, discussed above, the simulated volatility measure of FDI in Figure III.4. peaks for mid-level risk economies and decreases for both low and high risk economies resulting in a non-linear pattern of volatility in country risk. This suggests that aggregate measures of volatility in themselves cannot tell much about the actual characteristics of foreign investments. Both good and bad quality economies can have stable direct investments, although the cause of the low volatilities differs. Whereas in the former case the need for changing control over the assets is very low due to the low probability of negative changes in the demand, in the latter case, low volatility comes from the fact that the actual volume of investments is too low to induce changes in the desired levels of control, as the cost incurred by these changes outweighs their benefits.

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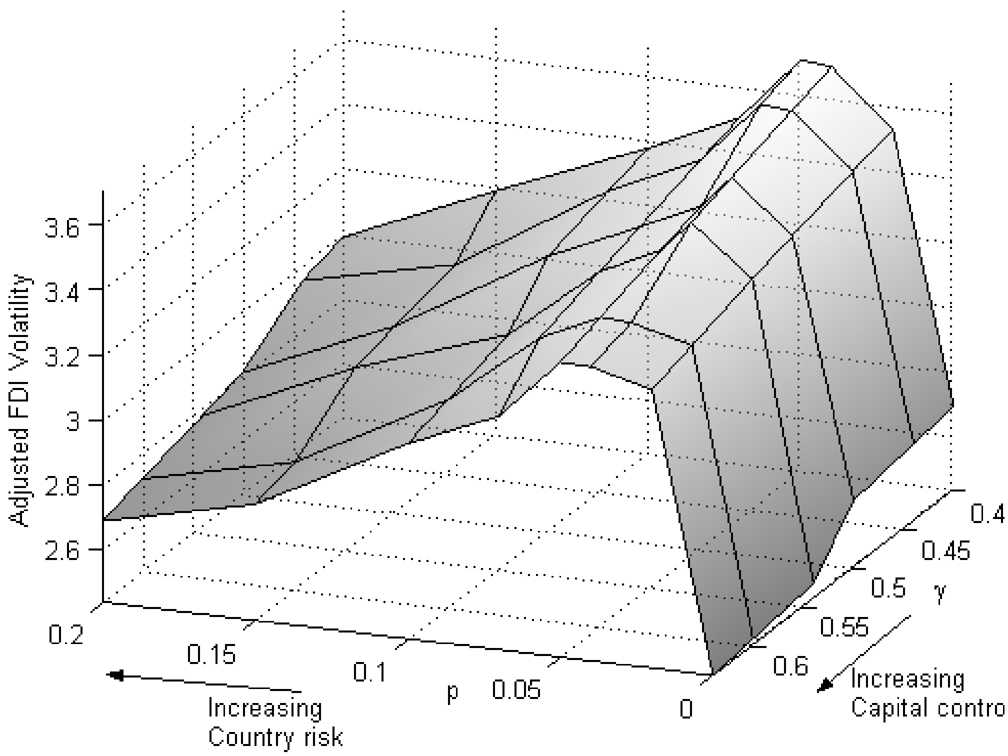
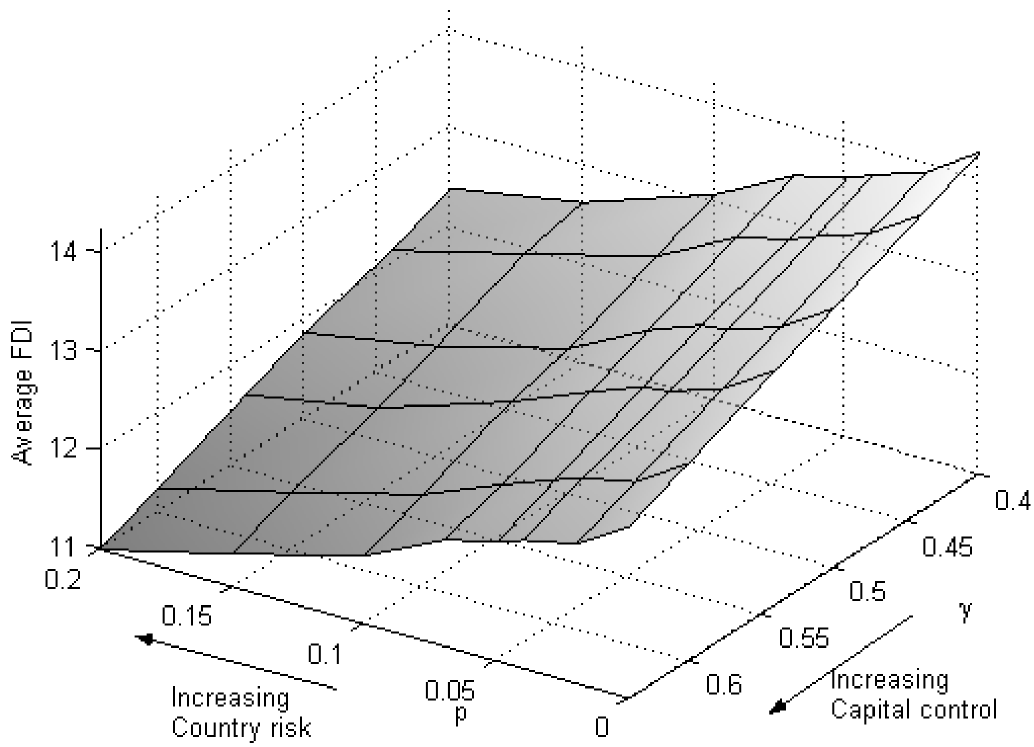
[13] Poisson jumps were assumed to be nondiversifiable therefore their effect on the trigger values of θ is going to be negative (see Dixit and Pindyck(1994)).

Figure III.4. Simulated adjusted FDI volatility in terms of country risk and severity of capital control, N=5000



The peculiar effect of country risk on the volatility of FDI also influences the impact of capital controls, creating nonlinearity in that variable's marginal effect as well. For every level of country risk the variability of the inward FDI stream decreases for economies with more restrictive capital control measures. Comparing capital controls for countries with different country risk characteristics, however, reveals that restrictive measures induce the most significant decrease on the volatility of FDI in countries in the mid and low ranges for country risk, whereas their effect diminishes for high risk economies. Capital controls increase the cost of changing ownership, inducing investors to wait longer, before they intervene. This makes FDI flows less volatile at each level of country risk. In high risk economies, however, the probability of financial distress increases the cost of waiting above the cost of exit, leading to a more volatile FDI flow at the same level of capital control compared to mid and low risk economies.This result is of particular importance for empirical analysis by shedding light on hidden microeconomic dynamics and revealing the major factors that are responsible for shaping patterns of the macro FDI data.

Figure III.5. Simulated average FDI in terms of country risk and severity of capital control, N=5000



The values in Figure III.5. indicate that country risk and capital control decrease the average amount of FDI investments in the economy over the whole project lifespan. As expected, the average volume of FDI is diminishing in both country risk and capital restrictiveness. Therefore, countries that attempt to decrease the volatility of capital flows by capital restrictions might face low levels of desired foreign direct investment flows. The negative impact of capital controls on the volume of FDI varies with country risk. when imposing capital controls, countries facing high probability of financial distress experience a larger negative impact on their incoming FDI flows than low risk economies. This outcome points to a policy paradox. The aim of capital controls is to offset the negative effects of country risk on the quality of capital flows. Nevertheless, our findings indicate that in the very case of high risk economies, the remedy has limited effect on improving the quality of foreign direct investments. Our simulations revealed that decrease in volatility comes with a sharp drop in the average level of FDI.

Figure III.6. Simulated average initial ownership share (b_0) in terms of country risk and severity of capital control, N=5000

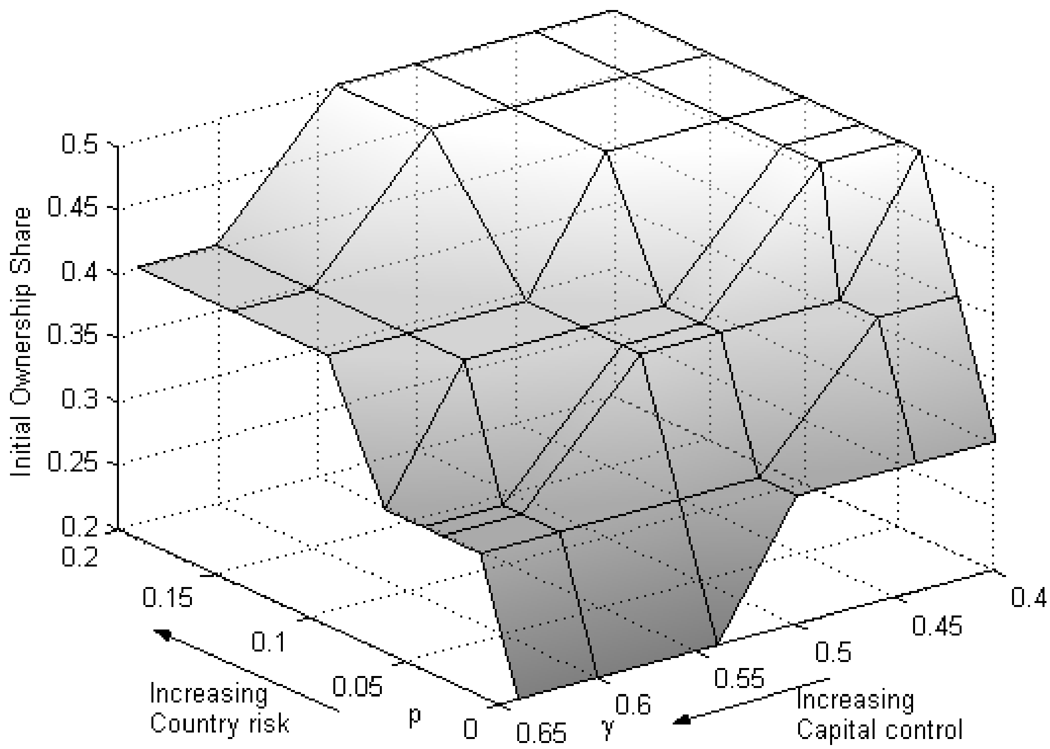
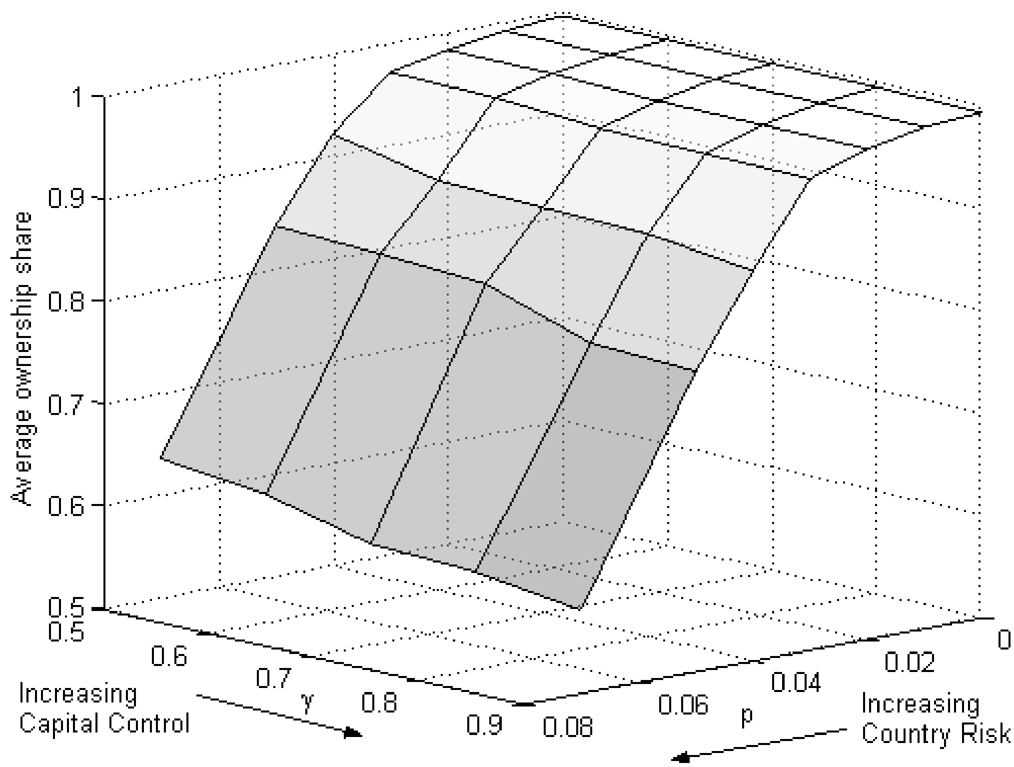


Figure III.6. shows the initial level of required control in terms of capital control and country risk. Increasing levels of capital control leads to lower amounts of initial ownership acquired by foreign investors. Capital controls induce foreign investors to share the risks of unfavorable occurrences with the local firms even risking the loss of their proprietary knowledge through the amplified spillover effects. On the other hand increased country risk leads to a higher level of initial ownership acquisition. As we saw country risk increases the trigger value of entry in higher risk economies together with the initial ownership stake that foreign investors acquire.

The overall amount of ownership, however, shows a very different picture from the initial acquisitions. Figure III.7. shows that despite the high initial ownership acquisition in high risk economies, the average ownership during the full period of the project is very low compared to safe economies.

Figure III.7. Simulated average ownership during the FDI life-span in terms of country risk and severity of capital control, N=5000



This implies that investors enter the market with a relatively high share, but decrease their stake very soon to reap the short term benefits of the high risk projects. It is potentially misleading, therefore, to merely consider the size of acquisitions, as during the lifetime of the projects it is very likely that foreign investors will decrease their stake in the project in economies with a high probability of financial distress. It is also important to note that capital controls decrease the willingness of foreign direct investors to stay in the economy. This effect is negligible in low risk economies, but becomes significant in high risk economies.

As a summary of the results of our model simulation we can argue that capital controls are effective in reducing the volatility of FDI flows only by reducing the actual amount of foreign direct investment and foreign presence (reduced ownership stake) in the economy. A country facing financial constraints has to take into consideration this effect, as other capital inflows have to be secured to satisfy the domestic demand for capital. This result is of particular importance for empirical analysis by shedding light on hidden microeconomic dynamics and revealing the major factors that are responsible for shaping patterns of the macro FDI data.

IV. Empirical Assessment of the Capital Controls Model

To assess the findings of our theoretical analysis this section is devoted to an empirical analysis of the stability characteristics of FDI flows. We analyze the effects of capital controls and country risk on FDI volatility. Based on our earlier analysis, transparency affects the amount of required ownership and the overall amount of FDI, with negligible impact on volatility. Transparency only affects volatility through its impact on country risk. Hence we can omit the transparency issues, when analyzing stability in the empirical assessment of volatility.

Empirical data on FDI is limited due to the short time series data available across economies and the limited number of countries reporting accurate data. To reproduce the simulation analysis we would need a very large amount of entry and exit times and real ownership rate data for an individual economy at changing levels of country risk and other business environmental factors. To overcome the lack of sufficient history we conduct the analysis on a cross section of economies with different country risk characteristics over a 20 year period. The panel study of FDI is believed to be better than a cross section approach as panel data allow for controlling for fixed effects, more informative data, more degrees of freedom, and more efficiency (see Baltagi and Kao(2000)). Inward and net foreign direct investment flows and stocks are available for a wide range of countries. We use these to assess the validity of our theoretical model. We use aggregate macroeconomic measures of volatility and average FDI in a particular economy to analyze stability of foreign direct investments. Based on our simulation results we derived testable hypotheses for the empirical investigation of these measures.

Hypothesis I. The aggregate volatility of foreign direct investments follows a nonlinear pattern in the country risk parameter: a hump-shaped curve. To test this hypothesis we need to include nonlinear terms of the country risk parameter:

$$CV_{it} = \alpha_i + f\left(icrg_{it}\right) + g(X_{jit}) + \epsilon_{it} \tag{23}$$

where CV_{it} is the volatility measure for country i in time period t, $f(icrg)$ is some function of the country risk measure (higher values of $icrg$ representing less risky economies), $g(X_{ijt})$ is a function of all other variables effecting volatility, α_i is a country specific constant, and ϵ_{it} is a white noise error term. According to our hypothesis, f should be a non-linear function of the country risk parameter.

Hypothesis II. As we could see from the simulation results, the effects of barriers to capital movements are different for different levels of country risk. For high risk economies we observed that policy incentives to reduce capital movements have a relatively smaller effect than in low risk economies. The overall effect of capital controls on volatility is weakly negative. To test this hypothesis we have to include cross effect variables that represent the joint effect of country risk and capital control:

$$CV_{it} = \alpha_i + f(icrg_{it}) + \beta_1 icrg_{it} \cdot cc_{it} + \beta_2 cc_{it} + f(X_{jit}) + \epsilon_{it} \tag{24}$$

where cc_{it} denotes some capital control measure, with lower levels of the variable representing less strict controls on cross-border capital movements. According to our hypothesis $\beta_1 > 0$,$\beta_2 < 0$.

A. Data and Estimation

For the empirical investigation we used data on net and inward FDI stock measured as a percentage rate of GDP. We collected data for 81 countries taken from UNCTAD Foreign Direct Investment Statistics for the 1980-2001 period. Table C.6. in the Appendix lists the countries included in the sample.

For our investigation, we created two subperiods: 1980-1989 and 1990-2001. The division was based on the expected structural break in the model due to the socio-environmental and political changes at the end of the 1980's that considerably altered the behavior of all types of capital flows and particularly FDI. To test for the actual time period of the structural breaks we conducted a panel rolling regression analysis. This analysis suggested that the most likely occurrence of a structural break in the regression coefficients occurs towards the end of the 80s. This supports our choice of the subperiods. Nevertheless, we repeated the analysis also by leaving out the 1987-92 period to account for the uncertainty in the timing of the structural break. Our estimation results are presented both for the restricted and unrestricted model. As the outcome of the two methods produces similar results in the following analysis, we rely on the unrestricted model to test our hypotheses.

We used net FDI flows, $netfdi$, as the basis for our volume and volatility measure. The choice of net FDI instead of the more commonly used inward FDI measure is an implication of our theoretical model, that focuses on overall FDI flows instead of just incoming FDI. For our estimations we first need to create a measure for the FDI volatility. We construct proxies for these in a two step process, described by Lensink and Morrissey(2001). To create uncertainty proxies they first extract the expected component of the particular variable with a forecasting equation. This forecasting equation is specified as a first or second-order autoregressive process, possibly extended with a time trend. Second, the uncertainty proxy is derived by calculating the standard deviation of the residuals from the forecasting equation (see also Aizenman and Marion(1993) for a detailed description of the method).

We follow this approach to create a proxy for the FDI volatility, by taking the standard deviation of residuals from the autoregressive equation for the net FDI flows, $netfdi$, of a particular country. We calculate, for each country in the data set, the standard deviation of the residuals of the following forecasting equations with lagged values over two periods and a time trend when the latter was significant.:

$$FDI_{it} = a_{i1} + a_{i2}T + a_{i3}FDI_{it-1} + a_{i4}FDI_{it-2} + e_{ti} \quad (25)$$

where FDI_{it} is the net FDI flow measure for country i at time period j. Variable T represents the time trend, a_{ij}, $j = 1..4$ are constants and e_{ti} is the error term. This equation is estimated for all countries over the 1980-2002 period. This is only an approximate measure of volatility, yet due to the fact that the time series available are rather short, more sophisticated measures of volatility are not justified. Our volatility measure, CV, was then constructed by extracting the estimated error term, $\widehat{e}_{ti}$, from Equation (25) for each individual country in our sample. The volatilities in the two assessment periods in our panel are calculated as the standard deviation of the extracted residuals over the subperiods 1980-1989 and 1990- 2001.

According to Nordal(2001), country risk is the unique risk faced by foreign investors when investing in a specific country as compared to alternative investing in other economies. It is very difficult to quantify country risk. As we are interested in foreign direct investment decisions we have to pick those indices that describe associated risks involved in these transactions. The three most relevant indices are Moody's sovereign risk ratings, the Institutional Investors Investment ratings (IIR) and the International Country Risk Guide index (ICRG). The Moody's index focuses more on a country's ability to service its debt payments, and not on the general health of the financial and business environment. Therefore, IIR and ICRG are better suited for our analysis, as they are general economic distress indices. We will use these two in our estimation. There is, however, a close correspondence between the Moody's index and the ICRG financial ratings. Erb et.al.(1996) show a rank order correlation of 68% between the two. Hence, as part of our ICRG index, we are also incorporating sovereign risk into our analysis.

The IIR rating is a survey based index containing leading international bankers' assessment on the general attractiveness of an economy's investment climate. On a scale from zero to 100, where 100 represents maximum creditworthiness, IIR is a weighted average of the survey responses, attaching greater weight to respondents with higher international exposure and more sophisticated country analysis systems. As the index is based on subjective risk evaluations it measures the general sentiment on a country's investment environment.[14] The IIR risk ratings were taken from the World Bank Database on Foreign Direct Investment over the 1979-1998 period .

According to Erb et. al.(1996) the ICRG composite index contains the most accurate information, especially its financial and economic composite ratings. Just like the IIR index, it also includes data on political, financial and economic risk factors to calculate risk indices in each of the categories as well as a composite index. Similarly to the IIR index, ICRG also ranges from zero to hundred, with higher index numbers reflecting lower overall risk. ICRG is the broadest measure that assesses risks associated with an economy. Recall that our economic distress parameter

[14] The components of the IIR index comprise a wide variety of political, economic and financial variables, like Economic Outlook, Debt Service, Financial Reserves/Current Account, Fiscal Policy, Political Outlook, Access to Capital Markets, Trade Balance, Inflow of Portfolio Investment and Foreign Direct Investment.

expresses the impact of changes in the business environment on the demand function. By its definition, the model's country risk parameter includes a wide range of distress factors, which calls for the use of ICRG, the broadest risk measure. Therefore, we rely predominantly on this measure in the following analysis. The ICRG measures were taken from the 2005 WDI online database for our sample period.

To test our second hypothesis on marginal transaction costs we collected data on capital controls. The capital control measure was taken from Prasad et.al.(2003) , who created a dummy variable that equals 1 for countries with capital control in a particular year. We created a summary measure by averaging the index values for the two subperiods for the individual countries. We have to note that these measures are far from perfect indicators of the existence of capital controls. They are not capable of indicating the absolute value of restrictions. Nevertheless, they can be used as relative measures to compare the restrictiveness of the government policy.

B. Estimation Results

To validate our hypotheses we employ a panel analysis. One problem with simple estimation methods is that some explanatory variable might be endogenous, and thus correlated with the error term, leading to biased estimates. It is also possible that some omitted variable affects both growth and the explanatory variables. According to Claessens et.al.(1995) governments usually consider total capital flow volatilities when deciding on different policy measures, not individual flows. Therefore, both the country risk and capital control variables can be treated as predetermined. They show that the cross relations between flows makes volatility of total flows independent of other flows. This allows us to ignore the endogeneity problem. The omitted variable bias can be successfully eliminated by using panel estimation. As we do not know the nature of the omitted variables but we can assume that they are closely related to fundamental country characteristics that drive our country risk and capital control variables, a well structured panel analysis is justified.

As we concentrate on the effects of capital control and country risk on FDI volatility other economic variables were excluded from the analysis. Including other macroeconomic factors, the estimates would ignore any effects operating through capital control's and country risk's impact on these variables. For example, capital controls may decrease GDP growth. By including this variable, we would not take account of capital control's impact on volatility that works through GDP. Also, there is high level multicollinearity between macro variables, like productivity, GDP growth, gross capital formation, with country risk, that validates the exclusion of these variables, when assessing country risk effects. As we noted earlier, the omitted variable problem that arises through neglecting these factors is eliminated by using panel estimation. If we have repeated samples for a cross sectional dataset and assume that the omitted variables are time invariant, we can effectively handle the bias that arises from omission of important explanatory variables. For this reason, we only retain the capital control variable, cc, the country risk composite measure,

$icrg$, and the inward foreign direct investment measure, $invfdi$. Due to the nonlinearity of $invfdi$ we took its logarithmic transformation. The inclusion of inward foreign direct investment is justified, by our previous simulation results, that indicate that higher risk economies attract larger FDI inflows. As we took net FDI flows to create our volatility measure we do not have an endogeneity problem due to the inclusion of $invfdi$. The distribution of the volatility measure, CV, showed a log-normal pattern so we took its logarithmic transformation for our estimation. Table IV.4. reports the panel regression estimates on the logarithm of the net FDI volatility proxy, $lncv$, for the different functional forms in $icrg$ and cc. We present two linear, five quadratic and one fractional polynomial regression to test the validity of our hypotheses.

Hypothesis I. Hypothesis I. derived from our theoretical model suggested that volatility of FDI is nonlinear in country risk. To derive the functional form of FDI volatility in terms of country risk, we estimate three different types of models: linear, quadratic and fractional polynomial panel models. The quadratic models differ from the simple linear panel models, by the inclusion of the squared country risk variable, $icrg^2$:

$$\textit{lncv}_i = \alpha + \beta_1 icrg_i + \beta_2 icrg_i^2 + \beta_3 icrg_i \cdot cc_i + \beta_5 cc_i + f(X_{ji}) + \epsilon_i \tag{26}$$

Fractional polynomial models with continuous covariates were first described by Royston and Altman(1994). Estimation methods based on these models are more flexible than simple linear and quadratic functions, by allowing more complex curvatures than simple hyperboles. At the same time these estimation methods do not suffer from the problem of edge effects and waves that are common in higher order polynomial estimation.

$$\textit{lncv}_i = \alpha + \beta_1 icrg_i^{(p_1)} + \beta_2 icrg_i^{(p_2)} + ... + \beta_m icrg_i^{(p_m)} + \beta_3 icrg_i \cdot cc_i + \beta_5 cc_i + f(X_{ji}) + \epsilon_i \tag{27}$$

where $p_1 < ... < p_m$ and for a power p

$$icrg^p = \begin{cases} icrg^p & \text{if } p \neq 0 \\ \log icrg & \text{if } p = 0 \end{cases}$$

The Altman-Royston fractional polynomial regression estimates the powers of the polynomials in Equation (27) together with their coefficients, by systematically searching for the best power or combination of powers from a set of possible power choices. To determine the best power combination, the deviance, defined as minus twice the log likelihood, is calculated for each power combination. The power combination with the lowest deviance has the best fit and is thus chosen as the favored model for the corresponding set of variables.

Figure IV.8. Predicted FDI volatility in terms of country risk ($icrg$)

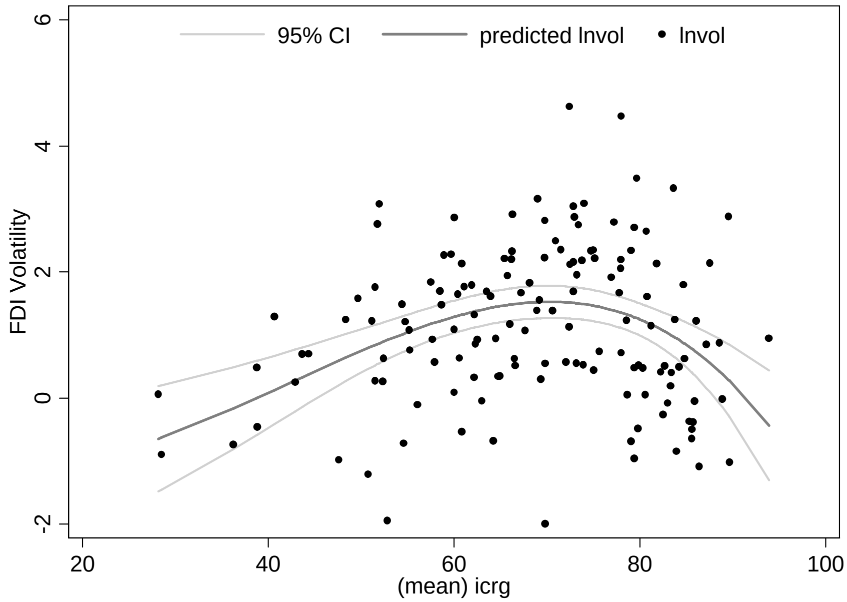


Figure IV.8. depicts a fractional polynomial fit to the FDI volatility data. The graph shows a clear nonlinear pattern in volatility, with high and low risk economies having lower average volatilities. The estimates in Table IV.4. underline this preliminary finding showing that the explanatory power of nonlinear models improve significantly compared to the simple linear model. Both the quadratic and multi variable fractional polynomial model show significant second/higher order effects of $icrg$ on volatility. The inclusion of the higher order terms improves the significance of $icrg$ in all cases.

The fractional polynomial model providing the best fit has powers (1,3) and deviance of -4253.8 The deviance of a linear model in $icrg$ has a deviance measure of -281.3, with a p value less than 0.001. As the nonlinear model has a lower deviance it indicates that FDI volatility is indeed non-linear in the country risk parameter. This finding is in line with the predictions of our theoretical model indicating the validity of the liquidity explanation of foreign direct investment flows, supporting our explanation of the nonlinearity that hinges on the complex effect of country risk on foreign direct investment decisions.

The best fitted multivariate fractional polynomial equation resulting from the estimation takes the following form:

$$\textit{lncv} = 0.91\left(\frac{icrg}{10}\right) - 0.007\left(\frac{icrg}{10}\right)^3 - 326.84 + \text{other factors} \tag{28}$$

Equation (28) highlights the pattern observed in our empirical findings generated by our model assumptions on delayed transactions with higher transaction costs. Increasing risk diminishes the volatility of FDI. Decreased market liquidity induces a higher cost of changing ownership to the investors that makes them reluctant to reduce their ownership in the firm even in cases of detrimental changes. In low country risk economies, the flexibility in changing ownership is much higher, yet it does not trigger higher volatilities as the possibility of a crisis situation is very low. As the probability of financial distress increases, the need for changing ownership increases as well. This overweighs the increment in the liquidity cost premium and results in an increasing volatility at first. As the liquidity premium further increases, firms reduce their operations rather then sell their assets. This creates a much lower average FDI with a low volatility. Also, the average lifespan of the projects decreases exponentially, as investors are more reluctant to enter high risk economies. This is a telling result, showing that the use of volatility as a measure of quality is generally misleading.

Hypothesis II. The effects of the capital control measure, cc, are less straightforward than the country risk results. This is partly due to our choice of capital control proxy. As Prasad et.al. (2005) note, capital controls are not water tight measures as there are different channels that can be used to evade capital controls, such as under- and overinvoicing of export and import contracts or transfer pricing schemes. They also note that the effectiveness of capital controls tends to diminish over time. The simple dummy variable, used in this analysis cannot fully capture the actual severity and effectiveness of the capital controls. The tests based on these measures are, therefore, only indicative.

According to Table IV.4., in the first subperiod (1980-89) there is a strong negative effect of capital controls on volatility. In all of our models, the cross product of the first subperiod dummy and cc have negative coefficients, significant at least at 5% level. This indicates that more restrictive capital control measures decrease the volatility of FDI as changing the levels of ownership becomes more expensive. This effect disappears in the second period. The coefficients change to positive and become highly insignificant. The reason for this finding might be due to two factors. The second period is characterized by a general globalization and deregulation of capital markets. The variability of the capital control measure then reduces significantly. This simultaneously reduces the ability of our model to differentiate clearly between open and closed economies. Second, the capital control proxy itself changes meaning in the second period, as new forms of capital controls are introduced. The second period volatility increase, captured by the time dummy, might also be due to the increased financial globalization, that is not captured by our capital control proxy.

We also tested the cross-effect between capital control and country risk in our model. We first created a high risk dummy for countries below 40 on the Institutional Investor's Index (IIR) (high overall sovereign and financial instability). Then we created a cross-effect variable with capital control and this high risk dummy $cc \times IIR40$. This allows us to assess whether there is a measurable change in the slope of cc. In our original model, the cross effect variable should have been the multiplicative term of $icrg$ and cc. Unfortunately, there is very little variation in cc and we needed to create a more dispersed measure. We used the IIR measure instead of the total $icrg$ as we were mainly interested whether financial risk changes the slope of cc and not total economic environmental risk. Table IV.4. shows a positive slope effect for high risk economies. The effect of capital control in low risk economies is, therefore, higher than for high risk economies. When imposing a time period restriction to avoid the uncertainty about the date of a structural break, the significance of the cross effect variable iir40xcc weakens. The implications of the cross effects do not change however. Nevertheless, it would be beneficial to further investigate the non-linearity assumption by finding more accurate data on capital controls.

The positive sign of the cross effect coefficient creates a Laffer curve pattern for the optimal amount of capital control in terms of country risk. It implies that imposing capital controls in higher risk economies reduces the volatility of FDI to a lesser extent than in low risk economies. This is a controversial finding in terms of its policy implications. The main motif behind capital controls is to reduce the uncertainty of capital flows mainly in high risk economies. Our analysis shows that the beneficial effect of capital control is very much dependent on country risk environment of the economy. Combined with the empirical findings on the behavior of the volatility of foreign direct investments, we can argue that capital controls reduce the quality of foreign direct investments. Their impact in high risk economies is less effective in decreasing the volatility. Countries considering the introduction of these measures should be aware of the policy implications on their desired resources of capital as well. Countries with very high levels of risk attempting to introduce restrictive capital control measures in order to limit the volatility of their capital flows have to take into consideration that their efforts might be in vain.

Together with the empirical findings on the behavior of the volatility of foreign direct investments, we can argue that capital controls reduce the quality of foreign direct investments. Their impact in high risk economies is negligible in terms decreasing the volatility of these flows but have a significantly negative impact on their average volume. Therefore countries considering the applications of these measures should be aware of their policy implications on their desired resources of capital as well. Countries with very high levels of risk attempting to introduce restrictive measures in order to limit the volatility of their capital flows have to take into consideration that their efforts to decrease volatility and thus the overall riskiness of their economies solely by the means of capital control might be in vain.

Table IV.4. Log FDI volatility regressions

lncv	Lin1	Lin2	Quad1	Quad2	Quad3	Quad4	Quad5	Frac1
icrg	.024	.015	.157	.152	.156	.153	.156	
	(.016)	(.016)	(.049)***	(.047)***	(.045)***	(.047)***	(.046)***	
icrg2			-.001	-.001	-.001	-.001	-.001	
			(.0004)***	(.0004)***	(.0003)***	(.0004)***	(.0004)***	
cc	.010	.559	-.136	.122	.253	.100		
	(.364)	(.422)	(.230)	(.295)	(.278)	(.290)		
cc $\times$ d1		-.837		-.755	-.780	-.766	-.702	-.599
		(.355)**		(.315)**	(.310)**	(.315)**	(.254)***	(.228)***
cc $\times$ iir40				.506	.428	.517	.546	.478
				(.265)*	(.246)*	(.264)*	(.251)**	(.216)**
Iicrg–1								.915
								(.197)***
Iicrg–2								-.007
								(.002)***
d2	.730	.374	.911	.421	.484	.445	.465	.542
	(.227)***	(.266)	(.161)***	(.231)*	(.226)**	(.230)*	(.221)**	(.174)***
cons	-.891	-.148	-3.926	-3.790	-3.872	-3.792	-3.856	1.111
	(1.010)	(1.025)	(1.518)***	(1.491)**	(1.417)***	(1.473)**	(1.456)***	(.187)***
N	144	144	144	144	144	144	144	144
Random effect chi2			71.295	89.623	130.663	102.641	103.322	309.881
R^2	.112	.159	.252	.266	.471	.352	.354	
sigma-u	1.082	1.044	.767	.806	.611	.744	.75	
RMSE	.763	.737						
Deviation FP								-4253.765
Deviation Linear								-281.326
Hausman-p	0.000	0.0129	0.4516	0.3202	0.4704	0.2846	0.3144	

Reported are the linear, quadratic and fractional polynomial estimations for Equation (**??**) and Equation (24) . The dependent variable is the logarithm of the volatility proxy from the autoregressive net FDI/GDP equations. The numbers in parentheses are the estimated heteroscedasticity-consistent standard errors. Outlier dummies are also included for Ireland, Hong Kong and Korea but not reported. Individual coefficients are statistically significant at the *10% , **5% or ***1% significance level. Hausman tests were also conducted. Reported are the p-values when comparing fixed and random effect models. In accordance with this the first two equations were estimated by a fixed effect model, while the remaining ones with a random effect panel model. The fractional polynomial model is also a random effect panel estimator.

Table IV.5. Log FDI volatility regressions when omitting 1987-1992 period

lncv	Lin1	Lin2	Quad1	Quad2	Quad3	Quad4	Quad5	Frac1
icrg	.027 (.016)*	.021 (.016)	.167 (.054)***	.166 (.054)***	.169 (.052)***	.165 (.053)***	.165 (.052)***	
icrg2			-.001 (.0004)***	-.001 (.0004)***	-.001 (.0004)***	-.001 (.0004)***	-.001 (.0004)***	
cc	-.211 (.357)	.237 (.430)	-.166 (.235)	.009 (.319)	.177 (.308)	.014 (.315)		
cc × d1		-.752 (.417)*		-.646 (.369)*	-.692 (.363)*	-.668 (.368)*	-.658 (.287)**	-.546 (.258)**
cc × iir40				.484 (.302)	.396 (.286)	.490 (.303)	.496 (.282)*	.433 (.243)*
Iicrg–1								.967 (.227)***
Iicrg–2								-.008 (.002)***
d2	.844 (.256)***	.522 (.309)*	1.137 (.185)***	.700 (.268)***	.771 (.263)***	.725 (.267)***	.727 (.256)***	.816 (.214)***
cons	-1.254 (.993)	-.661 (1.030)	-4.619 (1.691)***	-4.581 (1.722)***	-4.634 (1.661)***	-4.543 (1.707)***	-4.552 (1.673)***	.799 (.216)***
N	144	144	144	144	144	144	144	144
Random effect chi2			83.091	94.624	122.898	105.553	106.85	319.988
R^2	.161	.199	.29	.303	.445	.369	.369	
sigma-u	1.135	1.098	.761	.792	.634	.74	.744	
RMSE	.868	.853						
Deviation FP								-2318.99
Deviation Linear								-288.071
Hausman-p	0.0001	0.0734	0.1457	0.6620	0.6794	0.6504	0.5227	

Reported are the linear, quadratic and fractional polynomial estimations for Equation (**??**) and Equation (24) . The dependent variable is the logarithm of the volatility proxy from the autoregressive net FDI/GDP equations. The numbers in parentheses are the estimated heteroscedasticity-consistent standard errors. Outlier dummies are also included for Ireland, Hong Kong and Korea but not reported. Individual coefficients are statistically significant at the *10% , **5% or ***1% significance level. Hausman tests were also conducted. Reported are the p-values when comparing fixed and random effect models. In accordance with this the first two equations were estimated by a fixed effect model, while the remaining ones with a random effect panel model. The fractional polynomial model is also a random effect panel estimator.

V. SUMMARY

Recent financial crises have put capital controls in the focus of renewed investigation, attempting to quantify the impact of restrictive measures on the stability of capital flows in terms of their volume, composition and volatility. This paper investigated the effects of capital control on the qualitative properties of foreign direct investments. A stochastic dynamic decision theoretical model was introduced to examine how foreign investment decisions change when restrictive barriers on capital movements are implemented. The simulations of the theoretical model allowed us to generate different quality measures to assess the impact of capital control on foreign direct investments. By constructing the average life-span (duration), volatility, volume, ownership share and entry rate statistics we could uncover the underlying dynamics hidden in the macroeconomic data that is responsible for the low performance of the empirical studies of the matter in the prevailing literature. We found that capital controls induce a significant impact on the characteristics of long term foreign direct investment flows, therefore those studies evaluating the effects of capital controls by concentrating solely on short-term flows may lead to false conclusions on the desirability of such measures.

The results of the theoretical analysis showed that increasing capital controls reduce the maturity of FDI investments at each level of country risk, reflecting that strict capital control measures decrease the flexibility of the managers in deciding on the allocation of their investment proceeds, therefore they choose to reduce their operation in the market. Also the willingness towards risk sharing increases that was demonstrated by the diminishing average ownership shares in terms of capital controls and country risk. The simulations of foreign direct investment decisions uncovered a significant interaction between capital control and country risk, that resulted in a nonlinear relationship between these and the volatility and volume measures of FDI. We could show that introducing capital controls in riskier economies induces a sharper loss in terms of the stability of the FDI projects. This is a very important outcome of the model as the countries with high risk are more willing to impose constraints on capital flows, to attract more stable long-term capital, such as FDI. Knowing that the effect of these measures actually decreases the stability of FDI flows makes these means less attractive in these economies. On the short term, therefore, countries might face a structural change towards FDI, following capital restrictions, but the overall quality of these flows also reduces.

By conducting a simple empirical analysis we could validate the findings of the theoretical model. Analyzing the effects of capital controls on FDI confirmed the theoretical finding of a nonlinear relationship between capital control, country risk and the volatility of foreign direct investments. We could show that capital controls reduce the quality of foreign direct investments both in terms of volatility and volume. The efficiency of restrictive measures on capital in high risk economies was found to be negligible on the volatility of these flows and having a significantly negative impact on their average volume. Countries considering the applications of these measures on short-term capital flows aiming to improve the quality structure of their financial resources should therefore be aware of the counterproductive effect of their policy on foreign direct investments. Just as restrictions on the flow of goods and services causes global welfare losses, as we can see capital controls limit the amount of long term investments that deteriorates the governments attempts to provide stable financial backing for their excess investments. The stability of capital flows is of particular concern in economies with high country risk as the probability of occurrences of sudden capital outflows are the highest in these. Therefore it is of overriding importance to understand how the impact of these regulations on the quality of foreign direct investments alters when country risk changes. As the effects of capital controls depend heavily on the imposing country's economic environment, particularly its country risk characteristics, singling out positive examples from the past might not be sufficient validation for implementing such measures.

APPENDIX A. PROFIT FUNCTION

The following provides the derivation of the profit function used in the model. The instantaneous profit maximization problem of the firm takes the following form, assuming a Cobb-Douglas production function.

$$\Pi_F = \max_{L_D} P K_F^{\alpha} L_D^{1-\alpha} - cL_D \tag{A-1}$$

The first order conditions for the domestic and foreign owned firm take the following form, after substituting in for $K_i = F, D$

$$L_{DF} = \left(\frac{(1-\alpha)P}{c}\right)^{\frac{1}{\alpha}} \xi_0 K_0 \tag{A-2}$$

$$L_{DD} = \left(\frac{(1-\alpha)P}{c}\right)^{\frac{1}{\alpha}} (\xi_0 - \xi) K_0 \tag{A-3}$$

The output by each firm can be derived as the following:

$$\begin{aligned}
Q_{FS} &= (\xi_0 K_0)^{\alpha} L_{DF}^{1-\alpha} = \xi_0 b_0 K_0 \left(\frac{(1-\alpha)P}{c}\right)^{\frac{1-\alpha}{\alpha}} && \text{(A-4)}\\
Q_{DS} &= (K_0(\xi_0 - \xi))^{\alpha} L_{DD}^{1-\alpha} = K_0(\xi_0 - \xi) \left(\frac{(1-\alpha)P}{c}\right)^{\frac{1-\alpha}{\alpha}} \\
Q_S &= Q_{FS} + Q_{DS} = Q_D = \frac{\theta}{P} = (2\xi_0 - \xi) K_0 \left(\frac{(1-\alpha)P}{c}\right)^{\frac{1-\alpha}{\alpha}} \\
P^{\frac{1}{\alpha}} &= (2\xi_0 - \xi)^{-1} \theta K_0^{-1} \left(\frac{(1-\alpha)}{c}\right)^{-\frac{1-\alpha}{\alpha}} \\
\Pi_F &= P (K_0 \xi_0)^{\alpha} \left(\frac{(1-\alpha)P}{c}\right)^{\frac{1-\alpha}{\alpha}} (\xi_0 K_0)^{1-\alpha} - c \left(\frac{(1-\alpha)P}{c}\right)^{\frac{1}{\alpha}} \xi_0 K_0 \\
&= \xi_0 K_0 \left(\frac{(1-\alpha)P}{c}\right)^{\frac{1}{\alpha}} \frac{\alpha c}{1-\alpha} = \xi_0 K_0 \left(\frac{(1-\alpha)}{c}\right)^{\frac{1}{\alpha}} \frac{\alpha c}{1-\alpha} (2\xi_0 - \xi)^{-1} \theta K_0^{-1} \left(\frac{(1-\alpha)}{c}\right)^{-\frac{1-\alpha}{\alpha}} \\
&= \frac{\alpha c}{1-\alpha} \frac{\theta \xi_0}{2\xi_0 - \xi} \frac{(1-\alpha)}{c} && \text{(A-5)}
\end{aligned}$$

APPENDIX B. SOLUTION TO THE STOCHASTIC DYNAMIC IMPULSE-CONTROL PROBLEM

The general types of impulse control problems are described by Vollert, and Oksendal and Sulem in great detail (see Vollert(2003), Oksendal and Sulem(2002)). The solution to these problems generally does not allow for direct computation of $\widetilde{\phi}$. The approach followed by Vollert, and Oksendal and Sulem suggests to find a solution candidate for a given set of the decision variables, the specified stochastic processes and transaction functions. Usually, the solutions involve some form of numerical approach. After finding a candidate solution the next step is to prove that it is a unique solution to the problem. Oksendal and Sulem provide a set of these verification theorems to prove uniqueness. We can extend these by incorporating optimal stopping to obtain a combined verification theorem for jump diffusions and optimal stopping (see Vollert(2003), p.80). For the purpose of the study it is worth to summarize the results of these in a theorem. We only show the solution for switching between two impulse control problems as any number of switches can be derived recursively, starting with the latest switching between two processes.

THEOREM 1.1

Suppose there exists a continuous function $\phi(s, u, z) \in C^1(\mathbb{R}^2)$ satisfying the following properties:

(1.1) $\mathcal{A}\phi$ exists a.s. $G^x(d, \cdot)$, where $d \in \mathbb{R}^2$ and G is the Green measure of the jump-diffusion X. Function $\mathcal{A}$ is the generator function of ϕ, defined in the following way assuming that U follows an Ito diffusion process, with drift vector $\widehat{\boldsymbol{\mu}}$ and volatility vector σ:

$$\mathcal{A}\phi(s, u, z) = \frac{\partial \phi}{\partial s} + \widehat{\boldsymbol{\mu}}\frac{\partial \phi}{\partial u} + \frac{1}{2}u\boldsymbol{\sigma}\boldsymbol{\sigma}'u'\frac{\partial^2 \phi}{\partial u^2} + p\left(\phi(s, u_-, z) - \phi(s, u, z)\right) \qquad \text{(B-1)}$$

(1.2) For all $w \in \mathcal{W}$ the following generalized Dynkin formula holds[15]:

$$E^x\left[\phi(X^w_\tau)\right] = \phi(x) + E^x\left[\int_0^\tau \mathcal{A}\phi(X^w_t)dt\right] \qquad \text{(B-2)}$$

for all bounded stopping times τ that are bounded from above by the exit time for X^w for some bounded set in $\mathbb{R}^2$.

(1.3) $\{\phi(\vartheta, U_\vartheta, z)\}_{\vartheta\in\mathcal{T}}$ is uniformly integrable w.r.t. $\mathbb{P}^x$ for all $z \in \mathcal{Z}^a$ and $\vartheta \in \mathcal{T}$, where $\mathcal{T}$ is the set of all $\mathcal{F}_t$-stopping times; $\vartheta < \tau$.

(1.4) $\phi(X^w_t) \to 0$ as $t \to \infty$, a.s. $\mathbb{P}^x$ for all x

(1.5) Let us define the maximum operator as follows:

[15] See Oksendal et.al. (1998) for the the properties of the generalized Dynkin formula. They also show that the formual holds for a wide range of jump-diffusions.

$$\mathcal{M}^a\phi(s,u,z) \;:\; = \max_{\zeta^a\in\mathcal{Z}^a\setminus\{z\}}\left\{\phi(s,u^{\zeta},\zeta^a)-T^a(x,\zeta^a)\right\} \tag{B-3}$$

$$\mathcal{M}^\tau\phi(s,u,z) \;:\; = \max_{\zeta^p\in\mathcal{Z}^a}\left\{\phi(s,u^{\zeta^{a,p}},\zeta^p)-T^\tau(x,\zeta^p)\right\} \tag{B-4}$$

Then

(1.6) $\phi \geq \mathcal{M}^a$ and $\phi \geq \mathcal{M}^\tau\phi$ everywhere

(1.7) $\mathcal{A}\phi + f \leq 0$ almost everywhere w.r.t to G^x, where

(1.8) Define

$$\mathcal{C}^a = \left\{x\in\mathbb{R}^{n+1}\times\mathcal{Z}^a;\phi(x)>\mathcal{M}^a\right\} \text{,and } \mathcal{C}^\tau = \left\{x\in\mathbb{R}^{n+1}\times\mathcal{Z}^\tau;\phi(x)>\mathcal{M}^\tau\right\} \tag{B-5}$$

as the continuation region for the switch regime, $\mathcal{C}^a$, and the continuation region for the optimal stopping problem, $\mathcal{C}^\tau$.

Then

(1)

$$\phi(x) \geq V^w(x) \tag{B-6}$$

for all $w = w^a \cup w^\tau \in \mathcal{W}$ and all $x = (s,u,z)$

(2) If

$$\mathcal{A}\phi + f = 0 \tag{B-7}$$

for all $x = (s,u,z) \in \mathcal{C}^a \cap \mathcal{C}^\tau$, then we define the combined control strategy $\widehat{w} = \left(\widehat{t}_1,\widehat{t}_2,...,\widehat{t}_k,\widehat{\tau};\widehat{\zeta}_1\widehat{\zeta}_2,...\widehat{\zeta}_k,Z^p_\tau\right)$ as follows:

Put $\widehat{t}_0 = 0$ and for $j = 0,1,...,k-1$

$$\widehat{t}_{j+1} = \inf\left\{t>\widehat{t}_j, X^{(j)}_t \notin \mathcal{C}^a \text{ and } X^{(j)}_t \in \mathcal{C}^\tau\right\} \tag{B-8}$$

$$\widehat{\tau} = \inf\left\{t>\widehat{t}_k, X^{(j)}_t \in \mathcal{C}^a \text{ and } X^{(j)}_t \notin \mathcal{C}^\tau\right\} \tag{B-9}$$

where X^j_t emerges by applying the control $\left(\widehat{t}_1,\widehat{t}_2,...,\widehat{t}_k,\infty;\widehat{\zeta}_1\widehat{\zeta}_2,...\widehat{\zeta}_k,...\right)$ to X_t. If we choose $\widehat{\zeta}_{j+1}$ such that

$$\mathcal{M}^a\phi(\widehat{t}_{j+1},U_{\widehat{\zeta}_{j+1}},\widehat{\zeta}_{j+1}) = \widehat{\phi}(\widehat{t}_{j+1},U_{\widehat{\zeta}^-_{j+1}},\widehat{\zeta}_{j+1}) - T^a(X_{\widehat{\zeta}^-_{j+1}},\widehat{\zeta}_{j+1}) \tag{B-10}$$

and for $j > k < \infty$ choose Z^p_τ so that

$$\mathcal{M}^\tau\phi(\widehat{\tau},U_{\widehat{\tau}},Z^p_{\widehat{\tau}}) = \widehat{\phi}(\widehat{\tau},U_{\widehat{\tau}^-},Z^p_{\widehat{\tau}}) - T^\tau(X_{\widehat{\tau}^-},Z^p_{\widehat{\tau}}) \tag{B-11}$$

Then $\widehat{w} = w^a \cup w^\tau = \left(\widehat{t}_1, \widehat{t}_2, ..., \widehat{t}_k, \widehat{\tau}; \widehat{\zeta}_1 \widehat{\zeta}_2, ...\widehat{\zeta}_k, Z^p_\tau\right) \in \mathcal{W}$ and

$$\widehat{\phi}^a = V^{\widehat{w}}(x) = \widetilde{\phi}^a(x) \tag{B-12}$$

and the optimal combined impulse-control and optimal stopping strategy is given by:

$$\widehat{w} = \widetilde{w} \tag{B-13}$$

Proof

The proof is the same as the proof of the combined verification theorem by Vollert(2003), with the extension of Oksendal and Sulem(2002) and Framstadt(1997). Oksendal and Sulem(ibid.) generalize the Dynkin formula for jump-diffusions that is defined in Equation (B-2). With this extension the combined proof is similar to Vollert's. The conditions stated in Theorem I. are sufficient for the solution to exist. The actual proofs of the extended verification theorem can be found at Oksendal and Sulem(ibid.) and Vollert(ibid.) in greater detail. For the purpose of this study I restate the main result of the theorem. According to the theorem all candidates for the value function ϕ must be differentiable with respect to t and twice differentiable with respect to θ. This excludes the countable number of discrete jumps due to the occurrence of the $Poisson$ event in the region where it is not optimal to intervene. This region is called the continuation region and is denoted by $\mathcal{C}$. When X_t reaches the boundary of the continuation region then an impulse control is applied right away and an optimal action is chosen from $\mathcal{Z}$. This region is the so-called intervention region, denoted by $\widetilde{\mathcal{C}}$. Whenever the process reaches the boundary of the continuation region the optimal switch is determined by a maximum operator, $\mathcal{M}$.

This operation returns the system into the continuation region, where X evolves freely. According to the results of the verification theorem the optimal value function for the FDI problem can be obtained as the solution of a set of sufficient quasi-variational inequalities of the following form:

$$\mathcal{A}^i\phi(x) + g(x) \leq 0, i = a, \tau \tag{B-14a}$$
$$\phi(x) \geq \mathcal{M}^i\phi(x) \tag{B-14b}$$
$$\left(\phi(x) - \mathcal{M}^i\phi(x)\right)\left(\mathcal{A}^i\phi(x) + g(x)\right) = 0 \tag{B-14c}$$

where $g(x)$ is the instantaneous cash flow in the operation and $\mathcal{A}$ is the generator function of u.

The previous verification theorem holds for combined exit and impulse control problems as well, as the binary exit problem can be represented as a simple impulse control problem. Vollert provides the proof for the combined verification theorem. Our model assumptions ensure that the underlying functions and processes are well-behaved, thus Theorem 1.1. holds. Therefore we can use the quasi variational inequalities in Expression (B-14) to generate the optimal solution for our problem. Using this result we decompose our FDI problem into two separate problems: the operation phase with exit, also referred to as an intensity option with exit, and an entry decision problem or timing option that are solved in the following sections.

The intensity option with exit

Let us first define the following generator functions for the entry and operation phase, taking advantage from Ito's Lemma for well-behaved stochastic processes like X_t^a and X_t^e assuming that ξ and θ are independent:

$$\begin{aligned}
\mathcal{A}^e\phi(s,u^e,z^e) &= \frac{\partial\phi}{\partial s} + \widehat{\mu}\theta\frac{\partial\phi}{\partial\theta} + \frac{1}{2}\sigma\theta\frac{\partial^2\phi}{\partial\theta^2} + \\
&\quad + p\left(\phi(s,u^e(1-\eta),z^e) - \phi(s,u^e,z^e)\right)
\end{aligned} \tag{B-15a}$$

$$\begin{aligned}
\mathcal{A}^a\phi(s,u^a,z^a) &= \frac{\partial\phi}{\partial s} + \widehat{\mu}\theta\frac{\partial\phi}{\partial\theta} + \frac{1}{2}\sigma\theta\frac{\partial^2\phi}{\partial\theta^2} - \kappa\xi\frac{\partial\phi}{\partial\xi} + \\
&\quad + p\left(\phi(s,u^a(1-\eta),z^a) - \phi(s,u^a,z^a)\right)
\end{aligned} \tag{B-15b}$$

Let assume that we can separate the time effect by assuming that the following relationship holds:

$$L\phi(s,u,z) = e^{-\rho s}\psi(u) \tag{B-16}$$

Indeed, as our model has infinite horizon the assumption of time independent functions is justified. Using Equation (B-16) we can write up the following expression for the generator function:

$$\mathcal{A}\psi(s,u,z) = e^{-\rho s}\mathcal{A}_0\phi(u) \tag{B-17}$$

where $\mathcal{A}\phi(s{,}u{,}z)$ is defined as follows:

$$\begin{aligned}
\mathcal{A}_0^e\psi(u,z) &= \widehat{\mu}\theta\frac{\partial\phi}{\partial\theta} + \frac{1}{2}\sigma\theta\frac{\partial^2\phi}{\partial\theta^2} + \\
&\quad + p\left(\psi(u(1-\eta),z) - \psi(u,z)\right) - \rho\psi(u,z)
\end{aligned} \tag{B-18a}$$

$$\begin{aligned}
\mathcal{A}_0^a\psi(u,z) &= \widehat{\mu}\theta\frac{\partial\phi}{\partial\theta} + \frac{1}{2}\sigma\theta\frac{\partial^2\phi}{\partial\theta^2} - \kappa\xi\frac{\partial\phi}{\partial\xi} + \\
&\quad + p\left(\psi(u(1-\eta),z) - \psi(u,z)\right) - \rho\psi(u,z)
\end{aligned} \tag{B-18b}$$

As we discussed earlier in the operation phase the investor is able to decrease or increase the level of ownership in the range $\mathcal{Z}^e = [b_{\min}, b_{\max}] = [0,1]$ by paying the switching cost T. He also decides on whether to continue or abandon operation by choosing values from the $\mathcal{Z}^E$ binary action space. The corresponding impulse control strategy consists of a sequence of finite stopping times $t_i^a \in [\tau_I, \tau_E \wedge \tau_{b=0}]$ and $\tau^E \in [\tau_I, \infty]$ and corresponding impulse controls of ownership, $\zeta_i^a = b_{t_i}^a = b_i^a \in \mathcal{Z}^e$ and $\zeta_i^E = e \in \{0{,}1\}$.The optimization problem for a firm already operating is the following:

$$V_t = \tag{B-19}$$

$$= V^A(t,\theta_t,\xi_t,b_t) = \sup_{\substack{(\tau_E,w)\in\\ [0,\infty)\times\mathcal{W}}} \widetilde{\mathbb{E}}\Bigg[\int_{\tau_I}^{\tau_E\wedge\tau_{b=0}} e^{-\rho t}\left[b_t f(t,\theta_t,\xi_t,b_t) - C_M\right] dt$$

$$- \sum_{i:\tau_I\le t_i\le\tau_E} e^{-\rho t_i} T(t_i,\theta_{t_i},\xi_{t_i},b_{i-1},b_i,V^A_{t_i}) - e^{-\rho\tau_E} C_E\Bigg]$$

The maximum operators for the combined impulse-control optimal stopping problem can be represented by a double maximization problem for decreasing and increasing ownership stakes in the firm:

$$\mathcal{M}^a V^A(t,\theta_t,\xi_t,b_t) = \max_{b^*_F\in\mathcal{Z}\setminus\{b_F\}} \left\{V^A(t,\theta_t,\xi_t,b^*) - T(t_i,\theta_{t_i},\xi_t,b,b^*,V^A_{t_i})\right\} \tag{B-20a}$$

$$= \max\Bigg\{\max_{b^*_F\in\mathcal{Z},b^*_F>b_F} \left\{V^A(t,\theta_t,\xi_t,b^*) - T(t_i,\theta_{t_i},\xi_t,b,b^*,V^A_{t_i})\right\},$$

$$\max_{b^*_F\in\mathcal{Z},b^*_F<b_F} \left\{V^A(t,\theta_t,\xi_t,b^*) - T(t_i,\theta_{t_i},\xi_t,b,b^*,V^A_{t_i})\right\}\Bigg\}$$

$$\mathcal{M}^\tau V^A(t,\theta_t,\xi_t,b_t) = -C_E \tag{B-20b}$$

Expanding the value function we get the following set of quasi-variational inequalities for the operation regime, $X^a_t = (t, \theta_{t,},\xi_t,b_t)$, $X^a_t \in [\tau_I,\tau_E\wedge\tau_{b=0})\times\mathbb{R}^+\times\mathbb{R}^+\times[0,1]$ and $X^E_t = (t,\theta_{t,},\xi_t,0)$, $X^a_t \in [\tau_I,\infty)\times\mathbb{R}^+\times\mathbb{R}^+\times\{0,1\}$.

$$\mathcal{A}V^A - (r+p)V^A + pV^A((1-\eta)\theta,\xi,z^a) + bf(X_t) - C_M \le 0 \tag{B-21a}$$

$$V^A \ge \mathcal{M}^a V^A \tag{B-21b}$$

$$V^A \ge \mathcal{M}^\tau V^A \tag{B-21c}$$

where one of the inequalities is an equality. The inequalities in expression (B-21) reflect the optimal switch and operation decision. If (B-21a) holds as an equality, investors decide not to intervene into the system. They operate with the control they obtained earlier and generate discounted cash flows of $bf(X_t) - C_M$ at each instant. When (B-21b) holds as an equality switching the level of control becomes optimal. If (B-21c) becomes an equality investors choose to abandon their projects.

As Vollert(2003) notes, impulse control problems differ from the simple entry and exit models or stopping models described by Dixit and Pindyck(1994). For the simple optimal stopping models we have a single system of quasi-variational inequalities for each state, whereas in the case of impulse controls when b can take values continuously in the interval $[0,1]$ we have an infinite set of quasi-variational inequalities to solve.

The next question to answer is what form does the continuation region of the impulse-control problem take. According to its definition from Theorem 1.1 the continuation region in the switch and abandonment case are given by the following expressions:

$$\mathcal{C}^a \quad : \quad = \left\{x \in [\tau_I, \tau_E \wedge \tau_{b=0}) \times \mathbb{R}^+ \times \mathbb{R}^+ \times \mathcal{Z}^a; V^A > \mathcal{M}^a V^A\right\} \qquad \text{(B-22a)}$$

$$\mathcal{C}^\tau \quad : \quad = \left\{x \in [\tau_I, \infty) \times \mathbb{R}^+ \times \mathbb{R}^+ \times \mathcal{Z}^E; V^A > \mathcal{M}^\tau V^A\right\} \qquad \text{(B-22b)}$$

The intersection of these two determine the operation region for the firm. If any of (B-22) is violated, investors stop operation and either switch to another control level or entirely abandon operation.

To get a better understanding of the continuation region that enables us to derive simple decision rules, we have to take a further look into the relationship between our control variable and the source of uncertainty. Recall that the firm value and thus the foreign investment value is increasing in θ_t with b_t and ξ being constant. This is the outcome of the profit function being an increasing function of the demand parameter. For low levels of demand the cash flow function $b_t f_F(t, \theta_t, \xi_t, b_t) - C_M$ becomes negative and $b_t f_F(t, \theta_t, \xi_t, b_t) \to 0$. Hence for a sufficiently small level of demand, θ^{**}, a ceteris paribus downward adjustment of the ownership level is triggered. On the other hand, if demand becomes sufficiently high, so that it reaches a trigger level of θ^*, an upward switch in ownership occurs. High level of demand and thus higher future expected returns justify for paying the switching cost of increasing b. The actual trigger values depend also on ξ, the other environmental variable. The profit function increases in ξ. This will lead to an increasing pattern for θ^* in ξ representing increasing willingness to obtain control earlier if the intangible knowledge capital of the foreign investors is large. As the knowledge differential is large, the loss of expected profit due to knowledge spillovers decreases the expected cash flow stream by only a small amount proportionately, compared to the excess uncertainty cost arising from increased ownership. At the same time the lower trigger θ^{**} also increases, expressing an increased willingness for risk sharing in case of economic distress. For very low levels of ξ and θ it is beneficial simply to abandon the project and leave the host country. When the demand falls below a very low level, θ^E, it becomes beneficial for investors to simply abandon their investments, without any compensation. The optimal exit trigger should follow an increasing pattern in ξ.

By using these findings the continuation region can be represented as follows:

$$\mathcal{C}^a \quad : \quad = \left\{x \in [\tau_I, \tau_E \wedge \tau_{b=0}) \times \mathbb{R}^+ \times \mathbb{R}^+ \times \mathcal{Z}^a; \theta^{**}(t, \xi_t, b_t) < \theta_t < \theta^*(t, \xi_t, b_t)\right\} \qquad \text{(B-23a)}$$

$$\mathcal{C}^\tau \quad : \quad = \left\{x \in [\tau_I, \infty) \times \mathbb{R}^+ \times \mathbb{R}^+ \times \mathcal{Z}^E; \theta_t > \theta^E(t, \xi_t, b_t)\right\} \qquad \text{(B-23b)}$$

with corresponding upper and lower control levels of b^* and b^{**} and zero in case of exit. The abandonment value $\theta^E(t, \xi_t, b_t)$ is always less than or equal to the lower boundary $\theta^{**}(t, \xi_t, b_t)$. This is ensured by our initial assumption on the relationship between the abandonment cost and the transaction cost. In the continuation region inequality (B-21a) becomes an equality and the system evolves freely without any adjustments. Once the demand reaches the boundaries of the operation region, one of the inequalities of (B-21b) and (B-21c) becomes an equality. According to the definition of the maximum operator this yields the value matching conditions for the three free boundaries, θ^{**}, θ^{*},.θ^{E}.

We can write up these value matching conditions in the following way for the downward, upward ad exit boundaries:

Downward switch condition:

$$V^A(t,\theta^{**},\xi_t,b_t) = V^A(t,\theta^{**},\xi_t,b^{**}) - T(t,\theta^{**},\xi_t,b_t,b^{**},V_t^A), \tag{B-24}$$

Upward switch condition:

$$V^A(t,\theta^{*},\xi_t,b_t) = V^A(t,\theta^{*},\xi_t,b^{*}) - T(t,\theta^{*},\xi_t,b_t,b^{*},V_t^A), \tag{B-25}$$

Exit condition:

$$V^A(t,\theta_t,\xi_t,b_t) = V^A(t,\theta^{E},\xi_t,0) - T(t,\theta^{E},0,\xi_t,b_t,V_t^A), \tag{B-26}$$

It is important to note that both the trigger values, θ^{*}, θ^{**},θ^{E} and the optimal control levels, b^{*}, b^{**} depend on ξ and the current control level b. Hence for each level of knowledge differential and ownership, there exists an optimal intervention strategy. Therefore, as b is bounded both from above and below there might be levels of ownership where the optimal strategy would be intervention, but there is no room for further expansions or decrements. These cases impose restrictions on the model solution that has to be taken into account by the analysis.

Timing option, entry decision

Turning now to the entry problem, recall that knowledge spillovers are assumed to exist only after entering the host economy. This greatly simplifies the analytical environment. Without spillovers $d\xi = 0$, the dimension of the state variable reduces to one. The only environmental variable that affects decisions is θ, that follows the same process as before. The timing of the entry to the market can be described by the following optimization problem:

$$V^E(t,\theta_0,\xi_0,b_0) = \sup_{(\tau_I,b_0)\in[0,\infty]\times\mathcal{Z}^e} \widetilde{\mathbb{E}}\left[e^{-\rho\tau_I}\left(V^A(t_I,\theta_{t_I},\xi_{t_I},b_0) - T(t_I,0,b_0,\xi_{t_I},\theta_{t_I},V_{t_I}^A)\right)\right] \tag{B-27}$$

To determine the optimal level of initial ownership, the following maximum operator is introduced:

$$\mathcal{M}V^E(t,\theta_t,\xi_t,b) = \max_{b_0\in\mathcal{Z}^e}\left\{V^A(t,\theta_t,\xi_t,b_0) - T(t,0,b_0,\xi_t,\theta_t,V_t^A)\right\} \tag{B-28}$$

with the corresponding variational inequalities:

$$\frac{1}{2}\sigma^2\theta^2\frac{d^2V^E}{d\theta^2} + \widehat{\mu}\theta\frac{dV^E}{d\theta} - (r+p)V^E + pV^E((1-\eta)\theta,\xi,z^e) \leq 0 \tag{B-29a}$$

$$V^e \geq \mathcal{M}V^e \tag{B-29b}$$

where one of the inequalities is an equality.

Similarly to the intensity option with exit, we expect the continuation region to take the following form:

$$\mathcal{C} := \{x \in [0, \tau_I) \times \mathbb{R}^+ \times \mathbb{R}^+ \times \mathcal{Z}; \theta_t < \theta^I(t, b, \xi_t)\} \quad \text{(B-30)}$$

In the entry situation, we only have a one variable system as spillovers are not present at the time when foreign investors wait. Then the first stage problem reduces to an ordinary differential equation with a solution of the following general form:

$$V^E(t, \theta_0, \xi_0, b_t) = A\theta_0^{\delta_1} + B\theta_0^{\delta_2} \quad \text{(B-31)}$$

where A and B are constants and $\delta_1 > 0$ and $\delta_2 < 0$ are the roots of the following non-linear polynomial (see Dixit and Pindyck(1994)):

$$\frac{1}{2}\sigma^2\delta(\delta - 1) + \widehat{\mu}\delta + p\eta^\delta - p - \rho = 0 \quad \text{(B-32)}$$

To rule out bubble solutions, we have to assume that constant B that corresponds to the negative root δ_2 in Equation (B-31) is zero. Taking advantage of this we get the following simple solution for V^E:

$$V^E(t, \theta_0, \xi_0, b_t) = A\theta_0^{\delta_1} \quad \text{(B-33)}$$

The optimal entry value for the demand parameter, θ_I, can then be determined by using the same approach as in the exit case. The corresponding conditions are the following:

$$V^E(t, \theta_I, \xi_0, b_t) = V^A(t, \theta_t, \xi_t, b_t) - T(t, \theta_I, \xi_0, 0, b_0, V_0^A), \quad \text{(B-34)}$$

where

$$b_0 = \arg\max V^E(t, b, \xi_0, \theta_I) \quad \text{(B-35)}$$

The two equations have to be solved simultaneously to obtain the optimal initial ownership, b_0, and trigger value of entry, θ_I.

Numerical Solution of the model-Finite Difference Method The verification theorems themselves are not sufficient to provide a solution to our model. As the represented FDI decision problem is very complex simple analytical solution methods are not applicable. However, we can use the quasi-variational inequalities from Equation (B-21) to construct a numerical solution that satisfies the conditions of the impulse control verification theorem. We use the finite difference method to approximate the corresponding equations in the timing and intensity with exit problems.

To solve our two stage problem, we commence first with the firm's operation phase after foreign entry. To ensure convergence let us rewrite Equation (B-21a) by substituting θ with x where $x := \ln\theta$ and $V^A(t, \theta, \xi, b) := F(t, x, \xi, b)$ The related equation then takes the following form:

$$\frac{1}{2}\sigma^2 F_{xx} + (\widehat{\mu} - \frac{1}{2}\sigma^2)F_x - \kappa(b)\xi F_\xi - (r + p)F + pF(\ln(1 - \eta) + x, \xi, b) + bf - C_M \leq 0 \quad \text{(B-36)}$$

The numerical approximation with finite difference approach starts with a cubic discretization of the state space with respect to ξ, x, together with the action space of b.

$$
\begin{aligned}
x_{\min},\ \Delta x,\ 2\Delta x, ..., x_{\max},\ \text{where } x_t &= j\Delta x, -J/2 \le j \le J/2 && \text{(B-37a)}\\
\xi_0, -\Delta\xi, -2\Delta\xi, ..., 0 \text{ where } \xi_t &= \xi_0 - i\Delta\xi, 0 \le i \le I && \text{(B-37b)}\\
& \quad 0, \Delta b, 2\Delta b, ..., 1 && \text{(B-37c)}
\end{aligned}
$$

Threshold value, $\theta_{\max}$ has to be chosen far enough from the current θ, so that it will almost never be reached.

The resulting grid consists of $(N_x + 1)(N_\xi + 1)(N_{b_F} + 1)$ points. The (i, j, k) node on the grid is the point that corresponds to the actual level of the demand $x = j\Delta x$, the spillover $i\Delta\xi$ and ownership share $k\Delta b_F$. Function $F_{i,j,k}$ denotes the value of foreign operation to the investor with flexible ownership level and optional total exit at the point (i, j, k).

We approximate the derivatives in Equation (B-36) by the following forward differences (see Dixit and Pindyck(1994)):

$$
\begin{aligned}
F_{xx} &= \frac{F_{i,j+1,k} - 2F_{i,j,k} + F_{i,j-1,k}}{(\Delta x)^2} && \text{(B-38a)}\\
F_x &= \frac{F_{i,j+1,k} - F_{i,j-1,k}}{2\Delta x} && \text{(B-38b)}\\
F_\xi &= \frac{F_{i+1,j,k} - F_{i,j,k}}{\Delta\xi} && \text{(B-38c)}
\end{aligned}
$$

Substituting these values into Equation (B-36) and lagging by one period, we get the following difference equation that we will use to produce our numerical solution:

$$
\begin{aligned}
F_{i,j,k} &= && \text{(B-39)}\\
&= p^+ F_{i-1,j,k} + p^0 F_{i-1,j,k} + p^- F_{i-1,j,k} + \\
&\quad + \frac{\Delta\xi}{\kappa\xi}\left[p(F_{i-1,j,k}(\ln(1-\eta) + x, \xi) - F_{i-1,j,k}) + bf_{i,j,k} - C_M\right]
\end{aligned}
$$

where

$$
\begin{aligned}
p^+ &= \frac{1}{\kappa i}\frac{\sigma^2 + (\widehat{\mu} - \frac{1}{2}\sigma^2)\Delta x}{2(\Delta x)^2} && \text{(B-40a)}\\
p^0 &= 1 - \frac{1}{\kappa i}\frac{\sigma^2}{(\Delta x)^2} - \frac{r}{\kappa i} && \text{(B-40b)}\\
p^- &= \frac{1}{\kappa i}\frac{\sigma^2 - (\widehat{\mu} - \frac{1}{2}\sigma^2)\Delta x}{2(\Delta x)^2} && \text{(B-40c)}
\end{aligned}
$$

To complete the analysis we also have to define the terminal condition. This ensures that we obtain a unique solution if that solution exists. We assume that at the end of the project life-time (that is at infinity) foreign investors have to sell their assets. After all the comparative advantages of the foreign investors disappear they simply sell the firm at the then prevailing price. We observe that all the values of contraction and expansion depend on the current levels of ownership. The terminal condition represents the assumption, that after the comparative advantage of the firm disappears it cannot extract more profit from the host economy on average than from operating in his country of origin. The then prevailing price would be the discounted Cash Flow from further operation with no knowledge differentials in a Cournot type oligopoly. Therefore, the final sale value can be written as follows:

$$V^A(\infty,\theta_\infty,0,b_\infty) = b_\infty \frac{\alpha\theta_\infty}{2} - T(\infty,\theta_\infty,0,b_\infty,V^A_\infty) \tag{B-41}$$

We use our finite difference approximation to derive the end condition for the numerical solution. Equation (B-42) represents the corresponding end condition.

$$F_{N_\xi,j,k} = k\Delta b_F \frac{\alpha \exp(j\Delta x)}{2} - T(0,k\Delta b_F,F_{N_\xi,,j,k}) \tag{B-42}$$

Hull and White(1987) derived additional stability conditions to ensure stability of the numerical appoximations for the value function F. These determine the size of the grids for ξ and x in the following way:

$$\Delta\xi \;\leq\; \frac{\sigma^2}{(\widehat{\mu}-\frac{1}{2}\sigma^2)^2} \tag{B-43a}$$

$$\Delta x \;\leq\; \frac{\sigma^2}{\left|\widehat{\mu}-\frac{1}{2}\sigma^2\right|} \tag{B-43b}$$

In accordance with Inequalities (B-21b) and (B-21c) to derive the foreign investor's optimal decisions the following switch condition has to be checked at each instant in the numerical solution:

$$F_{i,j,k} \leq \max\left[\max_{k\neq k'}\left\{F_{i,j,k'} - T(i,j,k,k',F_{i,j,k'})\right\}, -C_E\right] \tag{B-44}$$

Expression (B-44) represents the numerical approximation of the combined exit and switch decision at each instant. First, we decide the maximum value that can be achieved by switching to another ownership level. Second, this maximum value is compared to the abandonment cost.

In case the value after the switch is smaller than the abandonment value, it is beneficial for investors to choose to quit and abandon their projects. When exit is optimal, the following numerical equality has to hold:

$$F_{i,j,k} = -C_E \tag{B-45}$$

If ownership switching is optimal, the inequality (B-44) becomes the following equality:

$$F_{i,j,k} = F_{i,j,k'} - T(i,j,k,k',F_{i,j,k'}) \tag{B-46}$$

Through checking the boundary and switching conditions at each node on the grid, we determine the optimal ownership level, k' for each (i,j,k) combination. If $k = k'$ the ownership structure stays the same and the system is still in the continuation region. If $k' > k$ then ownership expansion is optimal. The upper boundary of the continuation region can be found by selecting for each k the demand parameter level $j^*(i,k)$, (e.g. θ^*) for which k' exceeds k for the first time. Then the new level of ownership is set to k'. The lower bound can be found the same way, by determining $j^{**}(i,k)$, (e.g. θ^{**}) for which k' is for the first time smaller than k. If exit switching is optimal then inequality (B-44) becomes an equality: $F_{i,j,k} = -C_E$. The exit boundary for the operation can be found by determining the demand level $j^E(i,k)$, (e.g. θ^E) for which $F_{i,j,k}$ hits the Exit boundary for the first time.

By simple backward solution methods (see Wilmott(2000) for further reference) the problem can be easily solved. The only complication that arises is that the underlying process is a jump-diffusion implying that the defined grid for the backward solution may not match the after jump values of the underlying asset. Therefore we have to use some approximation around these values. According to Tavella and Randall(2000) this can be done by a simple extrapolation technique. In the numerical model presented above, we use a simple two-point intrapolation between the gridpoints to obtain the after jump values of the option and a four point extrapolation beyond the gridpoints in case of positive jumps. The accuracy of the underlying method is of the order $O(\delta\theta^2, \delta t, \delta\xi)$.

The solution to the timing problem is similar to the exit case. As we have a closed form solution for the value of waiting we do not need to discretize the quasi-variational inequalities in Expression (B-29). As we noted in the previous section, the solution to the entry problem can be simplified to a simple second order equation. Dixit and Pindyck(1994) provide an easy solution method to determine θ_I (e.g. $j^I(i,1)$) by writing up the discretized version of the value matching and smooth pasting conditions that arise from Equations (B-33) and (B-34):

$$A\theta^{\delta_1} = F(t,\theta_I,\xi_0,b_0) - T(t,\xi_0,\theta_I,0,b_0,F) \tag{B-47a}$$

$$\delta_1 A\theta^{\delta_1} = \theta^I \frac{\partial F(t,\theta,\xi_0,b_0)}{\partial\theta}|_{\theta=\theta_I} - \frac{\partial T(t,0,b_0,\xi_0,\theta,F)}{\partial\theta}|_{\theta=\theta_I} \tag{B-47b}$$

Combining Equations (B-47a) and (B-47b) we derive the following expression, for optimal entry for each level of b_0:

$$\left(\theta^I \frac{\partial F(t,\xi_0,\theta,b_0)}{\partial\theta}|_{\theta=\theta_I} - \frac{\partial T(t,\xi_0,\theta_I,0,b_0,F)}{\partial\theta}|_{\theta=\theta_I}\right)/\delta_1 = F(t,\theta_I,\xi_0,b_0) - T(t,\xi_0,\theta_I,0,b_0) \tag{B-48}$$

Using the discretization rules described above we get the equation that determines the simplified numerical variational inequality for entry:

$$F_{i,j,k} \leq \max_{k\neq 0}\left\{\left(\frac{F_{i,j+1,k} - F_{i,j-1,k}}{2\Delta x} j\Delta x - \frac{T_{i,j+1,k} - T_{i,j-1,k}}{2\Delta x} j\Delta x\right)/\delta_1 + T_{i,j,k}\right\} \tag{B-49}$$

In line with our previous analysis for the operational phase, entering the market becomes optimal if Inequality (B-49) becomes an equality. In every other case foreign investors choose to wait and see. Equation (B-50) below describes the condition that has to be checked at each instant in the entry phase.

$$F^A_{i,j,k} = \left(\frac{F^A_{i,j+1,k'} - F^A_{i,j-1,k'}}{2\Delta x} j\Delta x - \frac{T_{i,j+1,k'} - T_{i,j-1,k'}}{2\Delta x} j\Delta x \right) / \delta_1 + T_{i,j,k'} \qquad \text{(B-50)}$$

If $k^{'} > 1$ (thus $b_0 > 0$) then entry to the market becomes optimal, and the entry boundary θ_I at each initial level of knowledge differential can be found by selecting the demand parameter level $j^E(i,0)$ for which $k' > 1$ the first time. If demand reaches θ_I the initial ownership level b_0 is set to $k^{'}\delta b$ and the system switches to its operational phase.

The numerical solution procedure can be summarized as follows (see Vollert(2003), p.199):

1. Determine the systems of quasi-variational inequalities for the switching option.
2. Determine the systems of quasi-variational inequalities for the entry and exit options.
3. Discretize over knowledge differentials, demand, and ownership action space taking into account the possibility of jump occurrences.
4. Split up the numerical procedure to the operational phase and the initial entry problem.
5. Operation Phase:
   a. Determine the discrete approximations of each variational inequality in each state for each state of the knowledge differentials.
   b. Determine the boundary conditions: terminal, initial and upper and lower boundaries of the demand parameter for each state of knowledge differential.
   c. Go one step backwards in time (decrease gradually the knowledge differentials) and calculate the value of investment at each state.
   d. Check for optimal strategy whether switching to another state or exit is possible and optimal.
   e. Store the optimal switching strategy for each state.
   f. Go back to step 5(b) until the knowledge differentials approach zero.
6. Determine the operation value for each state and strategy.
7. Entry Phase:
   a. Determine the discrete approximations of each variational inequality in each state for each state of the knowledge differentials, by using the value matching and smooth pasting equations.
   b. Go one step backwards in time (decrease gradually the knowledge differentials) and calculate the value of investment at each state.

c. Check for optimal strategy whether entry is possible and optimal.

d. Store the optimal switching strategy for each state.

e. Go back to step 7(b) until the knowledge differentials approach zero.

By using the above numerical algorithm we can determine the time zero value of investing in the domestic firm in each state for all the possible initial values for the underlying stochastic process together with the optimal ownership strategy.

Capital Control

The solution to the problem with capital control is similar to the basic model with substituting the different profit and impulse cost functions.

APPENDIX C. SUMMARY DATA TABLE

Table C.6. Selective Data of Sample Countries for the two subperiods N=83

	country	period	netfdi	invfdi	cc	iir	icrg	lncv
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Argentina	period 1	1.24	7.01	1	34.94545	43.66667	0.695958
2	Argentina	period 2	8.985714	16.05714	0.333333	32.84444	67.21923	1.669294
3	Australia	period 1	10.99	15.53	0.454545	81.81818	79.41666	0.4796708
4	Australia	period 2	10.12143	27.2	0	70.08889	81.23462	1.147705
5	Austria	period 1	3.6	5.011111	1	83.56364	85.58334	-0.6466096
6	Austria	period 2	2.185714	11.11429	0.083333	85.75555	85.75385	-0.3803858
7	Bahamas, The	period 1	17.26	28.58	1	85	.	1.980119
8	Bahamas, The	period 2	-5.557143	26.00714	1	86.66666	74.98462	2.349672
9	Bahrain	period 1	-7.26	8.5	0	57.06364	60.41667	1.650036
10	Bahrain	period 2	35.25714	56.97857	0	51.04445	72.85384	3.041754
11	Barbados	period 1	9.78	10.73	1	32.33636	.	0.0023994
12	Barbados	period 2	10.90714	12.57857	1	39.03333	.	0.4421786
13	Belgium	period 1	7.66	17.52	0	78.12727	80.58334	0.0498064
14	Belgium	period 2	11.19167	50.00833	0	80.1	82.26154	0.413871
15	Botswana	period 1	36.08	62.69	1	35.3	68.91666	1.389481
16	Botswana	period 2	13.2	25.72143	0.666667	44.43333	77.95	2.054029
17	Brazil	period 1	-3.98	9.4	1	40	55.25	0.7592736
18	Brazil	period 2	4.014286	12.74286	1	32.11111	63.96539	1.613764
19	Bulgaria	period 1	0.05	0.05	1	45.50909	64.25	-0.6811252
20	Bulgaria	period 2	10.00714	10.78571	1	23.46667	65.43462	2.21361
21	Canada	period 1	8.48	19.4	0	88.71818	84.25	0.4911769
22	Canada	period 2	-0.9571429	23.72143	0	82.1	83.8	1.246393
23	Chile	period 1	10.84	11.3	1	37.24545	54.41667	1.485036
24	Chile	period 2	35.13572	43.20714	0.916667	52.81111	75.16538	2.218478
25	China	period 1	2.2	2.32	1	65.96364	64.91666	0.347194
26	China	period 2	20.32143	22.52857	1	55.95555	71.50769	2.351442
27	Colombia	period 1	4.96	5.65	1	47.38182	57.91667	0.5708713
28	Colombia	period 2	11.13571	13.34286	1	42.1	62.18462	1.321849
29	Costa Rica	period 1	24.06	24.65	0.818182	22.09091	57.66667	0.931703
30	Costa Rica	period 2	27.65	28.27143	0.416667	29.08889	72.85384	1.689735
31	Croatia	period 1	0	0	1	36.42727	.	-0.7076995
32	Croatia	period 2	7.392857	12.17857	1	20.64444	70.93	2.493264
33	Cyprus	period 1	13.35	15.9	1	38.21818	64.5	0.9409711
34	Cyprus	period 2	20.67143	25.96429	1	51.97778	77.98462	2.197819
35	Czech Republic	period 1	0	0	1	52.37273	.	0.2033715
36	Czech Republic	period 2	23.10714	24.15714	0.5	54.41111	77.215	2.791809
37	Denmark	period 1	2.54	5.4	0.818182	72.40909	83	-0.0793513
38	Denmark	period 2	-1.2	20.99286	0	77.94444	85.91924	-0.0527297
39	Dominican Republic	period 1	5.47	5.47	1	19.74545	48.33333	1.246655
40	Dominican Republic	period 2	19.15	19.43571	0.916667	21.14445	66.24615	2.329651
41	Ecuador	period 1	8.3	8.3	0.181818	33.37273	51.16667	1.223408
42	Ecuador	period 2	25.65	26.38572	0.166667	23.03333	59.68462	2.281077
43	El Salvador	period 1	4.39	4.78	1	8.227273	38.83333	-0.4605984
44	El Salvador	period 2	9.364285	10.07857	0.5	18.38889	65.76923	1.940706
45	Estonia	period 1	0	0	1	66.35455	.	-0.0924453
46	Estonia	period 2	25.55714	29.96429	0.333333	32.36666	74.02	3.089552
47	Finland	period 1	-0.7	2.34	1	76.71819	84.83334	0.6263884
48	Finland	period 2	-10.8	11.77143	0.083333	73.96667	84.69615	1.796563
49	France	period 1	-0.02	5.5	1	84.72727	79.83334	-0.4814047
50	France	period 2	-5.778572	15.27857	0	87.96667	80.77692	1.610686
51	Germany	period 1	-1.87	4.6	0	94.6	.	-1.620135
52	Germany	period 2	-3.271429	13.12857	0	90.91111	83.9577	-0.8452057
53	Greece	period 1	10.91	16.29	1	53.50909	60	0.0894824
54	Greece	period 2	6.15	9.935715	0.5	49.72222	72.0423	0.5691848
55	Guatemala	period 1	13.43	13.43	0.818182	15.6	40.66667	1.290218
56	Guatemala	period 2	17.93571	18.01429	0	21	62.31538	0.8592616
57	Honduras	period 1	5.12	5.12	0.909091	14.14545	44.33333	0.7025106
58	Honduras	period 2	19.72143	19.72143	0.25	16.45555	58.52692	1.70222
59	Hong Kong, China	period 1	491.29	497.29	0	71.33636	72.41666	4.627619
60	Hong Kong, China	period 2	94.75714	207.4643	0	64.73333	78.01539	4.474073
61	Hungary	period 1	0.17	0.17	1	50.18182	66.5	0.6244522
62	Hungary	period 2	29.67143	31.33571	0.833333	45.7	72.98077	2.873901
63	Iceland	period 1	-0.05	1.39	1	54.11818	79.08334	-0.6868508
64	Iceland	period 2	-0.6642857	4.521429	0.5	57.57778	80.33077	0.4769474
65	India	period 1	0.34	0.34	1	48.63636	52.83333	-1.946983
66	India	period 2	2.307143	2.571429	1	42.98889	62.16923	0.3273001
67	Indonesia	period 1	26.11	26.15	0	50.2	49.66667	1.58323
68	Indonesia	period 2	33.92857	34.86428	0	49.02222	61.91923	1.791707
69	Iran, Islamic Rep.	period 1	2.7	2.7	1	19.01818	36.25	-0.7378126

	country	period	netfdi	invfdi	cc	iir	icrg	lncv
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
70	Iran, Islamic Rep.	period 2	1.257143	2.342857	1	27.45555	64.76154	0.3458756
71	Ireland	period 1	114.38	134.42	1	65.77273	79.66666	3.487453
72	Ireland	period 2	65.37857	90.2	0.166667	72.22222	83.65	3.330135
73	Italy	period 1	0.19	3.32	1	74.7	79.41666	-0.9573079
74	Italy	period 2	-3.635714	7.485714	0	75.52222	78.01154	0.7186649
75	Jamaica	period 1	19.14	19.3	1	16.54545	54.75	1.211031
76	Jamaica	period 2	29.12857	35.79286	0.5	24.37778	69.76154	2.225365
77	Japan	period 1	-2.51	0.34	0	95.42727	89.66666	-1.017254
78	Japan	period 2	-5.492857	0.85	0.5	91.43333	85.63077	-0.4965846
79	Jordan	period 1	7.79	8.49	1	37.8	51.5	0.2746883
80	Jordan	period 2	17.49286	16.89286	0.583333	27.33333	68.15769	1.82946
81	Kazakhstan	period 1	0	0	1	66.35455	.	0.1694222
82	Kazakhstan	period 2	27.58571	28.14286	1	26.01111	69.01	3.159399
83	Korea, Rep.	period 1	1.8	2.24	1	60.3	69.8	-1.993518
84	Korea, Rep.	period 2	0.8714285	4.328571	1	67.87778	78.67917	0.0508156
85	Kuwait	period 1	-7.62	0.12	0	65.85455	62.5	0.9257457
86	Kuwait	period 2	-11.76429	1.028571	0	52.55556	72.48846	2.120197
87	Latvia	period 1	0	0	.	66.35455	.	0.4077072
88	Latvia	period 2	11.75	20.55714	0.2	30.03333	73.4	2.747403
89	Lebanon	period 1	0.05	1.13	0	14.10909	28.5	-0.89676
90	Lebanon	period 2	2.65	3.985714	0	20.74444	55.18077	1.078531
91	Lithuania	period 1	0	0	1	66.35455	.	-0.2662327
92	Lithuania	period 2	12.81429	12.99286	0.25	29.23333	72.86	2.160732
93	Malaysia	period 1	17.29	21.02	0	65.20909	66.58334	0.5137046
94	Malaysia	period 2	26.99286	43.51429	0.5	64.47778	76.92693	1.916681
95	Malta	period 1	21.39	21.39	1	64.2	66	1.17478
96	Malta	period 2	33.2	36.56429	1	63.66666	79.41154	2.707834
97	Mauritius	period 1	3.43	3.44	1	22.83636	.	-0.3257456
98	Mauritius	period 2	7.407143	9.785714	0.5	43.47778	.	1.195889
99	Mexico	period 1	10.31	10.55	0.727273	45.17273	58.66667	1.48123
100	Mexico	period 2	13.91429	14.98571	0.5	42.25555	70.62692	1.385113
101	Netherlands	period 1	-12.28	15.71	0	87.43636	88.91666	-0.0177371
102	Netherlands	period 2	-14.42143	41.70714	0	89.04444	86.40769	-1.088393
103	New Zealand	period 1	3.87	9.13	0.454545	70.92727	83.41666	0.4030688
104	New Zealand	period 2	30.3	42.81429	0	67.55556	80.7	2.648192
105	Nicaragua	period 1	5.18	5.18	1	6.463636	28.16667	0.0622707
106	Nicaragua	period 2	35.00714	35.13572	0.5	9.622222	51.95385	3.080668
107	Norway	period 1	9.22	11.21	1	84.87273	87.16666	0.8513268
108	Norway	period 2	-0.4571429	15.42143	0.416667	80.94444	88.58846	0.8769864
109	Oman	period 1	13.39	13.41	0	49.9	60	1.090181
110	Oman	period 2	15.55714	15.69286	0.5	51.52222	75.64616	0.7403314
111	Panama	period 1	16.25	56.43	0	34.16364	51.75	2.763237
112	Panama	period 2	-12.28571	48.70714	0	25.02222	66.29616	2.915255
113	Paraguay	period 1	4.05	6.78	0.818182	35.75455	52.33333	0.2616384
114	Paraguay	period 2	9.428572	11.71429	1	29.66667	67.65769	1.069661
115	Peru	period 1	5.58	5.76	0.545455	24.9	38.75	0.4858456
116	Peru	period 2	12.4	13.22857	0.333333	21.85555	61.10385	1.767529
117	Poland	period 1	-0.03	0	1	19.79091	47.58333	-0.9793357
118	Poland	period 2	10.52857	11	1	35.21111	73.76539	2.186402
119	Portugal	period 1	13.04	14.68	1	53.72727	73.16666	0.5514562
120	Portugal	period 2	12.94286	22.18571	0.25	67.77778	79.88077	0.518183
121	Romania	period 1	0	0	1	33.34546	50.75	-1.211132
122	Romania	period 2	8.242857	8.571428	1	29.13333	60.85	2.134441
123	Saudi Arabia	period 1	17.24	18.12	0	69.88182	57.5	1.838281
124	Saudi Arabia	period 2	15.52857	16.75	0	56.46667	72.39231	1.129745
125	Singapore	period 1	50.59	71.69	0	77.2	79.08334	2.340269
126	Singapore	period 2	50.74286	102.5786	0	81.17778	87.54616	2.141405
127	Slovak Republic	period 1	0	0	1	16.5	.	.
128	Slovak Republic	period 2	10.09286	11.26429	1	28.84444	74.76	2.334934
129	Slovenia	period 1	0	0	1	20.4	.	-0.4996459
130	Slovenia	period 2	7.478571	10.78571	0.75	34.62222	78.58	1.231115
131	South Africa	period 1	3.6	15.06	1	49.85455	58.5	1.695457
132	South Africa	period 2	-0.6714285	16.48571	1	41.71111	69.2	1.553585
133	Spain	period 1	3.15	5.18	1	69	73.91666	0.5265877
134	Spain	period 2	6.757143	20.52857	0.666667	75.51111	77.7923	1.669899
135	Sweden	period 1	-5.76	4.09	1	80.38182	86.08334	1.22508
136	Sweden	period 2	-14.87143	21.79286	0.25	76.45556	82.69615	0.5125957
137	Switzerland	period 1	-10.14	10.85	.	95.27273	93.91666	0.948607
138	Switzerland	period 2	-38.25	26.05	0	92.46667	89.55769	2.881458
139	Taiwan	period 1	4.48	5.26	.	71.1	.	-0.0352122
140	Taiwan	period 2	-5.292857	7.721428	.	77.74445	.	1.048019
141	Thailand	period 1	4.74	4.85	1	53.70909	63	-0.045296
142	Thailand	period 2	15.47143	17.02857	1	60.5	73.22308	1.952548
143	Trinidad and Tobago	period 1	27.55	27.77	1	47.80909	58.91667	2.270407
144	Trinidad and Tobago	period 2	71.24286	73.55714	0.333333	34.31111	69.77692	2.815896
145	Tunisia	period 1	50.32	50.41	1	42.74545	51.5	1.759743
146	Tunisia	period 2	60.02143	60.20714	1	42.54445	69.35	0.296491
147	Turkey	period 1	12.19	12.71	1	28.72727	52.41667	0.6292551
148	Turkey	period 2	7.578571	8.935714	1	41.48889	56.06538	-0.1050961
149	Ukraine	period 1	0	0	1	66.35455	.	-1.474476
150	Ukraine	period 2	5.435714	5.971428	1	23.92222	63.52	1.688486
151	United Arab Emirates	period 1	2.12	2.25	0	60.01818	54.58333	-0.7168277
152	United Arab Emirates	period 2	2.128572	3.478571	0	59.21111	75.0423	0.4420688
153	United Kingdom	period 1	-5	13.36	0	88.42728	83.33334	0.1929845
154	United Kingdom	period 2	-13.36429	24.21429	0	87.12222	81.83077	2.131578
155	United States	period 1	-1.16	4.65	0	95.31818	85.33334	-0.3685114
156	United States	period 2	-1.95	9.364285	0.333333	89.83334	82.51923	-0.2605246
157	Uruguay	period 1	9.24	11.68	0	33.1	60.58333	0.6343447
158	Uruguay	period 2	7.078571	8.428572	0.25	36.95555	69.81538	0.5493299
159	Venezuela, RB	period 1	2.55	3.2	0.545455	48.04546	60.83333	-0.5344893
160	Venezuela, RB	period 2	11.42857	17.12857	0.5	35.21111	66.18077	2.200328
161	Vietnam	period 1	0.98	0.98	1	.	42.9	0.2506412
162	Vietnam	period 2	32.19286	32.19286	1	26.62857	60.04231	2.865443

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