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Abstract

We present a model of investment under uncertainty about fundamentals, using a global games approach. Goldstein & Razin (2003) show that there is an information based trade-off between foreign direct investment (FDI) and portfolio investment (PI) which rationalizes some well known stylised facts in the literature - the relative volatility and reversibility of foreign direct investment versus portfolio investment. We extend their result and show that uncertainty about fundamentals does not imply a multiplicity of investment outcomes even when there is an information-based trade-off between direct investments and portfolio investments. In our paper, uncertainty about fundamentals actually helps narrow down the set of possible equilibria. Hence we find that the equilibrium outcome does not exhibit co-ordination failure.

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1 Introduction

Recent work by Razin, Mody and Sadka (2002), Razin (2002), Goldstein and Razin (2002) in the investment literature highlight the importance of distinguishing between foreign direct investment and portfolio investment, in order to understand the potential economic growth incurred by some (small open) countries. It is argued that only foreign direct investment (FDI) carries the seeds that can lead towards stable economic growth. Portfolio investment's (PI) high volatility cannot ensure sustained economic growth.

The current literature recognizes that the risks associated with portfolio investment are mainly due to the difficulties in realizing foreign direct investments.¹ A foreign investor choosing to invest in a recipient or host country faces higher entry costs for direct participation within an industry, due to initial setup costs and uncertainty about fundamentals (i.e. asymmetric information at the entry level), and higher exit costs due to the difficulty of reselling a firm (i.e. asymmetric information at the exit level). These costs increase the observed volatility associated with portfolio investments, since only the foreign investors with "superior managerial skills" (Razin, 2002) will commit to FDI.

Hence, both foreign direct and portfolio investments are plausible investment choices, with opposite characteristics (in terms of risk-returns) and with opposite effects on a recipient country's potential for economic growth. Multiple equilibria can arise since there is an "information-based trade-off between direct investments and portfolio investments" (Goldstein, and Razin, 2002). In particular, informational asymmetries due to the different natures of FDI- and PI-type investment projects and to the degree of (institutional, capital markets and corporate governance) transparency can tilt investor's decisions towards one form of investment versus another. Razin, Sadka and Coury (2002) point out how an economy might go through "boom-bust cycles of investment supported by self-fulfilling expectations".

This paper formalizes a model of investment under uncertainty (due to informational asym-

¹For a survey on the "challenge" of foreign direct investment see the latest "Foreign Direct Investment Survey" by The World Bank (2002).

metries and noise in the degree of “transparency”) using a global games approach.² We show that uncertainty does not by itself imply a multiplicity of investment outcomes even when there is an information-based trade-off between direct investments and portfolio investments and noise in the degree of transparency. In our framework uncertainty about the degree of transparency always helps pin down an equilibrium (i.e. state-contingent) strategy and hence an equilibrium outcome from the set of possible multiple equilibria that exist.

Our work shows that the conditions which link foreign direct investments to portfolio investments always lead to a clear-cut outcome about investment decisions. In our model rational agents exploit the higher order beliefs determined by the degree of noise in transparency by endogenously affecting the information-based trade-off uncovered by Goldstein and Razin. This enables them to pin down an equilibrium strategy and to select *individual* equilibrium outcomes that may lead the recipient country to end up with a larger (smaller) share of FDI relative to PI.

The rest of the paper is structured as follows. Section 2 motivates our work by reviewing recent empirical and theoretical contributions in the literature on investment flows among countries. We highlight some stylized facts that help us develop our model, which is described in Section 3 in the case of complete information. The role of higher order beliefs in determining equilibrium strategies is analyzed in Section 4 in the case of incomplete information. Section 5 concludes and discusses the normative implications and possible extensions of our work.

2 Motivation

Razin (2002) verifies that FDI’s contribution to domestic investment and output growth dominates over the contributions stemming from portfolio equity flows and international loans. The gains to the host country from FDI are determined by the informational value of

²For a review of global games see, Morris and Shin (2001; 2002).

FDI: The hands-on-management style of direct investments enables foreign direct investors to operate only in sectors with good economic growth prospects. This has also an indirect effect because it spurs the domestic economy to invest in particular sectors, thereby leading to economies of scale and positive spill-over effects to the rest of the economy. These latter effects will be more or less pronounced depending on the nature of the investment technology and of the degree of trade-openness of the recipient country (Razin, Sadka, Coury, 2002).

The “informational value” of FDI poses also a problem of asymmetric information between buyers and sellers of investment projects. As highlighted by Goldstein and Razin (2002), common knowledge about the direct investors’ information-advantage - on where, when and why to invest in particular sectors of the host country - reduces the resale price that a direct investor may get when deciding to exit from the host country. This higher exit cost, due to the difficulty of reselling a firm (i.e. asymmetric information at the exit level), implies that only investors that have a low probability of having to resell early will end up undertaking direct investments. Portfolio investors are then by default only short-term investors, which is why empirically portfolio investments exhibit a much larger volatility than direct investments.

A corollary of this result is that increased transparency - i.e. a more efficient institutional framework, warranting, among other things, higher capital markets and corporate governance transparency - in the host country could lead to a higher direct investment share by mitigating the informational asymmetry inherent in the nature of direct investments. In a more transparent environment a buyer could distinguish whether the seller of an investment project is motivated by, say, personal liquidity needs or by bad information about the expected profitability of an investment project. This would lead to higher resale prices, larger fractions of direct investments relative to portfolio investments and a lower (positive) “volatility differential” between portfolio and direct investments.

Indeed, another empirical stylized fact highlighted by Goldstein and Razin is that developed countries exhibit lower volatility differentials between PI and FDI relative to developing

countries. The empirical importance of transparency is also confirmed by Gelos and Wei (2003). The authors find that herding among funds (i.e. among portfolio investors) tends to be more prevalent in less transparent countries.³

On the theoretical front Goldstein and Razin show that the information-based trade-off between the two forms of investment may lead to a multiplicity of equilibria. The equilibrium outcomes depend on various assumptions about the setup costs of an investment project, the probability of being hit by a liquidity shock faced by a foreign investor and the degree of (capital markets and corporate governance) transparency.

In a noisy economic environment with various assumptions about the degree of (capital markets and corporate governance) transparency, any equilibrium outcome (i.e. a pooling equilibrium, or a separating equilibrium) is possible depending on the exogenous probability faced by a foreign investor of being hit by a liquidity shock that forces her to resell the investment project ahead of time and by the presence of setup costs for undertaking a certain investment project (a proxy for uncertainty at the entry level). Informational asymmetries between buyers and sellers may be stronger (weaker) depending on a particular scenario faced by investors.

This paper explicitly accounts for varying degrees of transparency due to some noise incurred by investors when observing some fundamental variables (such as institutional efficiency, capital and corporate governance transparency, and also the financial liquidity conditions of other foreign investors).^{4,5} We show how the (imperfect) degree of transparency can help

³In our work we make no distinction between investors purchasing equities and bonds issued by foreign companies. We acknowledge that differentiating between foreign loans and foreign equity shares is relevant for understanding the sustainability of financial crises faced by a host country, as highlighted, among others, by Krugman (1999). An extension of the model to include this additional distinction between investment sources is left for future work.

⁴Acemoglu, Johnson, Robinson, and Thaicharoen (2002), Acemoglu, Johnson and Robinson (2002), and Acemoglu and Johnson (2003) provide convincing arguments for the importance of institutions for long-term economic growth.

⁵“Transparency” is therefore really a “catch-all” expression in our model. On the contrary, Goldstein and Razin make a clear distinction between the liquidity conditions characterizing foreign investors and the level of (capital markets and corporate governance) transparency in determining equilibrium outcomes.

to pin down an equilibrium outcome in the presence of noise that leads to informational asymmetries between foreign investors. In our framework noise leads to higher order beliefs that are exploited by rational agents to select an optimal (i.e. noise-contingent) equilibrium strategy.

The contributions of our work can be summarized as follows: First, we formalize the results in the recent (theoretical and empirical) contributions to the investment literature by using the global games framework as a tool for explicitly allowing for heterogeneity among foreign investors. This allows us to endogenize the relevance of asymmetric information in determining the relative shares of direct relative to portfolio investments in the recipient country. In particular, we think of our paper as a complementary contribution to the literature discussed above, that explicitly accounts for the role of informational asymmetries in determining types of investment flows. Second, our results have a clear and intuitive normative implication. Lower noise (higher transparency) leads to more direct investments relative to portfolio investments and lower volatility differentials between the two types of investment.⁶ Third, while this work focuses only on a static game between investors, it suggests that in a (repeated) dynamic setup a country might move through investment cycles characterized by different degrees of the various types of investment forms.

3 Economic Environment

This section of the paper outlines the setup of the model. The economic environment here is similar to the one found in Goldstein & Razin (henceforth GR, 2002). There are N (identical) foreign investors who wish to invest in a small open developing economy. Each investor has the same fixed amount of capital, k , to invest in a particular investment project within the country. Two types of investment projects exist within this small open economy. The first form of investment is direct investment (DI), where the foreign investor commits to a project that has a long term payoff. The second type of investment, portfolio investment (PI), is one

⁶Our normative result fully reconciles with the conclusions in Goldstein and Razin (2002).

where investors invest in financial markets and this is viewed as having short-term payoffs. Initially, we assume that the investor is only allowed to invest their capital, k , in either direct investments or in portfolio investments and cannot put only a fraction of his investment into either type.

Investor i has the following payoff structure:

$$\pi(a_i, n, x) = a_i[q((n+1)k, x)k - \frac{\gamma}{2}(k+c)^2] + (1-a_i)[((\bar{\pi}(x) + d(nk, x))k - \frac{\theta}{2}k^2)] \quad (1)$$

where $\gamma > \theta \geq 0$, $a_i \in A_i = \{0, 1\}$, $n \in \{0, 1, \dots, N-1\} = \sum_{j \neq i} a_j$ and $x \in \mathbb{R}$ is a random variable denoting the value of fundamentals within the small open economy. The variable a_i denotes an action taken by investor i and equals 1 if the investor decides to invest in DI and 0 if investing in PI. n is then defined as the total number of investors who decide to invest in DI. If investor i decides to invest in DI, then they face an initial setup cost, c , of acquiring information about the direct investments, but receives a return, $q((n+1)k, x)$ from investing their capital, k . The return from direct investments, $q((n+1)k, x)$ is assumed to be non decreasing in n and x . The greater the number of people that invest in DI, i.e. the higher n is, the greater the price, $q(\cdot)$ and the greater the revenue acquired, $q(\cdot)k$.⁷ Similarly, investing in financial markets (i.e. PI) allows an investor to diversify away risk. Hence, portfolio investors receive an average per share dividend, $d(nk, x)$, and have an average per share resale price, $\bar{\pi}(x)$ from holding stocks and shares.

The choice for an investor is to decide between direct investments and portfolio investments.

The return from direct investments, q depends on both the aggregate amount of capital invested into DI, but also on the actual value of fundamentals (i.e. the state of the economy).

The return from portfolio investments arises from the resale value of the shares held by the

⁷The economic environment being considered here is for a developing economy. The assumption that returns are non decreasing in aggregate capital is derived from the idea that there are positive spillovers from incorporating more capital, leading to increasing returns to scale for a developing country. This assumption may not be so reasonable for a developed country.

investors, along with any dividends generated by holding those shares. The average per share price, $\bar{\pi}(x)$ depends on the actual value of fundamentals, whilst the dividends are generated by firms which depend on the amount of capital invested in the economy, and the actual value of fundamentals.

Consider first a game, Γ , of complete information. Each investor observes a private signal about the true value of fundamentals and chooses between the two types of investment opportunities based upon this private signal. Defining the difference in payoffs between choosing DI and PI as :

$$\begin{aligned}\Delta\pi(n, x) &= \pi(a_i = 1, n, x) - \pi(a_i = 0, n, x) \\ &= [q((n+1)k, x)k - \frac{\gamma}{2}(k+c)^2] - [((\bar{\pi}(x) + d(nk, x))k - \frac{\theta}{2}k^2)]\end{aligned}$$

The payoff function is assumed to satisfy the following properties (i.e. given the functions $q, \bar{\pi}$ and d , and the parameters k, c, γ and θ , the payoff function π satisfies these properties):

A1 Continuity and Differentiability

$\forall n \pi(a_i, x, n)$ is a continuous and differentiable function of x

A2 Monotonicity: $\Delta\pi(n, x)$ is an increasing function of x , i.e. $\frac{\partial\Delta\pi(n, x)}{\partial x} \geq 0 \forall x \in [\underline{X}, \bar{X}]$.

$$\text{i.e. } \frac{\partial q((n+1)k, x)}{\partial x} > \frac{\partial((\bar{\pi}(x) + d(nk, x))k)}{\partial x}$$

This increasing differential in returns is consistent with the fact that in developing countries, the link between direct investment flows and domestic investment growth rates is much stronger than the corresponding link between portfolio investment flows and domestic investment growth rates. This is consistent with the observation that direct investment flows usually take the form of "greenfield" investments, as opposed to portfolio investments, which focus more on "mergers and acquisitions" of existing assets. Thus, in general, direct investments are conducive to higher domestic investments, economic growth rates and investment returns.⁸

⁸Evidence on the linkage between different forms of investment flows and domestic investment growth rates for developing countries can be found in Mody and Murshid (2004).

Moreover, direct investments to developing countries tend always to be associated with some forms of external intangible assets compared to portfolio investment flows. These more qualitative, management-related, differences between the two investment forms also account for part of the increasing differential in returns.⁹

A3 Strategic Complementarity: The greater the number of investors choosing DI, the greater is player i 's incentive to choose invest in DI.

$$\Delta\pi(n, x) \geq \Delta\pi(n - 1, x)$$

$$\text{i.e. } [q((n + 1)k, x) - [(\bar{\pi}(x) + d(nk, x))] \geq [q((n)k, x) - [(\bar{\pi}(x) + d((n - 1)k, x))]$$

$$q((n + 1)k, x) - q((n)k, x) \geq d(nk, x) - d((n - 1)k, x)$$

This assumption is consistent with the observed increased importance of *global* or external factors relative to *local* factors as drivers of direct investment flows. Albuquerque et al. (2004) document that the importance of global factors - such as G-3 average bond rates, the growth rate of world per capita GDP, the slope of the US yield curve, and the emerging markets bond spreads - in explaining the growth rates and variability of foreign direct investment flows has progressively increased after 1990. This result is suggestive of an increased integration of world capital markets which has triggered larger and larger flows of foreign direct investment relative to portfolio (and bond) investment flows towards developing (and emerging markets) countries.

The idea of strategic complementarity is also closely related to unexploited scale economies, increasing returns to scale, and spillover or network effects from direct investments. There is some evidence that these effects tend to be stronger the higher the number of foreign direct investors, i.e. as some form of clustering or spatial agglomeration occurs.¹⁰

⁹On this point see also Goldstein and Razin (2003), Razin (2002), and Albuquerque (2003).

¹⁰See the discussion in Mody et al. (2004), and, in particular, the references therein to Borensztein et al. (1988). Note also, that we are focusing on developing countries which lack a developed stock market. There is also counter-evidence provided by Lane and Milesi-Ferretti (2003a, 2003b): these authors document that in developed economies with highly developed financial structures the preferred investment tool is in the form of portfolio investment. It is therefore perfectly plausible that the returns from portfolio investments may be at least as high as the returns from direct investments for more developed countries.

A4 Indifferent values for fundamentals

A4.1 $\exists \bar{x} < \infty$ solving $\Delta\pi(0, \bar{x}) = 0$,

i.e. $\exists \bar{x}$ s.t. $[q(k, \bar{x})k - \frac{\gamma}{2}(k+c)^2] - [((\bar{\pi}(\bar{x}) + d(0, \bar{x}))k - \frac{\theta}{2}k^2)] = 0$

A4.2 $\exists \underline{x} > -\infty$ solving $\Delta\pi(N-1, \underline{x}) = 0$,

i.e. $\exists \underline{x}$ s.t. $[q(Nk, \underline{x})k - \frac{\gamma}{2}(k+c)^2] - [((\bar{\pi}(\underline{x}) + d((N-1)k, \underline{x}))k - \frac{\theta}{2}k^2)] = 0$

The idea that there exist some lower and upper threshold values for fundamentals is consistent with the fact that local factors, alongside global factors, are equally important determinants of direct and portfolio investment flows. Albuquerque et al. (2004) show that local factors - such as domestic GDP growth rates, the overall domestic tax burden, financial and institutional development measures - are very important even after accounting for their correlation with global factors. Especially during periods of global distress, local factors can be fundamental for preventing massive outflows from a particular country, i.e. they become dominant for understanding an investor's behavior. This suggests that there are (extreme) situations in which a rational investor will focus mainly, if not exclusively, on the local factors or country-specific fundamentals irrespective of other investors' behavior and of global factors. In our model this occurs whenever the representative investor's perception of local factors is extremely bad or extremely good.

Assumption **(A.1)** establishes a continuity and differentiability condition for the value of fundamentals (the exogenous variable), while **(A.2)** establishes that the higher the value of fundamentals, the greater the player's incentive to choose DI. Assumption **(A.3)** states the condition in the payoff structure such that this game is a game of strategic complements. In general, the greater the other players' strategy profile, the greater is player i 's incentive to increase his strategy. Finally, assumption **(A.4)** requires that for a sufficiently high (low) values of the fundamentals, player i will always choose DI (PI), i.e. for a set of values of the

fundamentals, investing in DI (PI) is a strictly dominant strategy (see Appendix 5 for the intuition).

An important remark is that assumptions A1 to A4 provide sufficient conditions for the existence of dominance regions, along which each action is strictly dominant. This fact provides this setup with the necessary global game structure, i.e.

$$\forall x < \underline{x} \quad \Delta\pi_i(n, x) < 0 \text{ and } \forall x > \bar{x} \quad \Delta\pi(n, x) > 0 \quad \forall n$$

These dominance regions, depicted in figure (1), are the shaded areas. In other words: $\forall x > \bar{x}$ action 1 is a strictly dominant strategy and $\forall x < \underline{x}$ action 0 is a strictly dominant strategy.

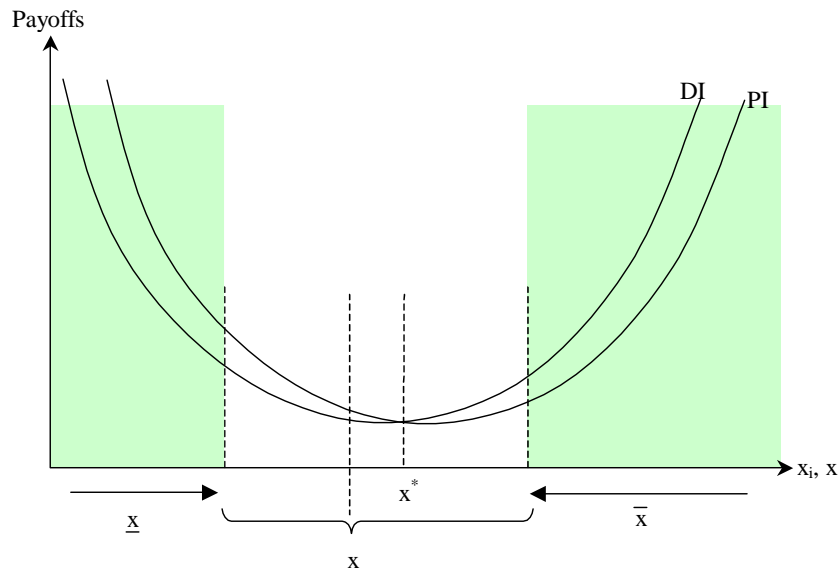


Figure 1:

The basic idea of the dominance regions in this case of complete information can be seen as follows. In this game of complete information, each investor's private signal coincides with the true value of the fundamentals. Let x^* denote the indifference point where $\Delta\pi(0, x^*) = 0$ (to be defined more formally in the next section). The higher x is compared to x^* , the greater

the difference in payoffs between direct investments and portfolio investments. Hence, given (A.1) - (A.4), for $x \gg x^*$, the more incentive there is for everyone to pick DI. Similarly, given (A.1) - (A.4), for $x \ll x^*$, the more incentive there is for everyone to pick PI. Thus, given their signal about the fundamentals, one of three outcomes will occur. Investors will either pool towards DI (for $x > x^*$) or PI (for $x < x^*$) or there will be some fraction of investors picking DI and some picking PI (for $x = x^*$). Thus there exists a multiplicity of equilibrium outcomes in the case where investors have complete information, given that there are infinite strategy profiles.

4 Incomplete Information

Now, suppose that each the investor observes a private signal of the fundamentals, x_i , and the private signal each investor observes depends upon the true value of fundamentals x , distorted by some noise: $x_i = x + \varepsilon_i$

Without loss of generality, we will assume that x is uniform distributed over \mathbb{R} and the noise ε_i is normally distributed with mean 0 and standard deviation σ .¹¹ We also assume ε_i is *i.i.d.* across the investors. Based upon this private signal, an investor decides whether to invest in direct investment or portfolio investment.

The basic idea regarding the dominance regions in this case of incomplete information is outlined first and can be seen in figure (2). For a given value of x (drawn from its distribution), investor i , forms beliefs about where other people lie on the distribution. Conditioning on both x and σ yields the dominance regions. An investor chooses the type of investment he wishes to undertake based upon his beliefs about what others will do depending upon his observation of x_i .

¹¹Improper priors (with infinity mass) are fine as long as we are concerned only with conditional beliefs. It is also possible to work with a more general noise structure but it will not change the main result. For more details on these issues see Morris and Shin (2000).

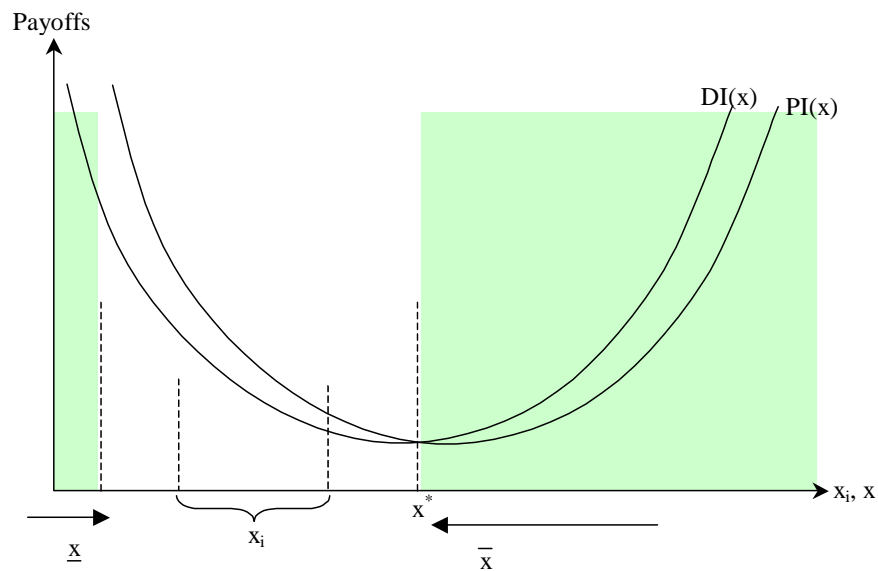


Figure 2

Let x^* represent the value of fundamentals at which an investor would be indifferent between choosing DI and PI. Consider the case where the value of the signal that the investor gets is very low, $x_i \ll x^*$. Then, he can construct bounds on where he believes other people lie in the distribution based upon his knowledge of σ . If this constructed upper bound is less than x^* , then the investor would consider investing in PI, (since the expected payoff is greater) but also believe that everyone else will do the same. Hence, he will invest in PI. Thus by an induction argument, it is possible to increase the limit of the upper bound until it equals x^* . Then the lower bound of the investor with the lowest realisation of ε , becomes \underline{x} . This can be seen in figure (3).

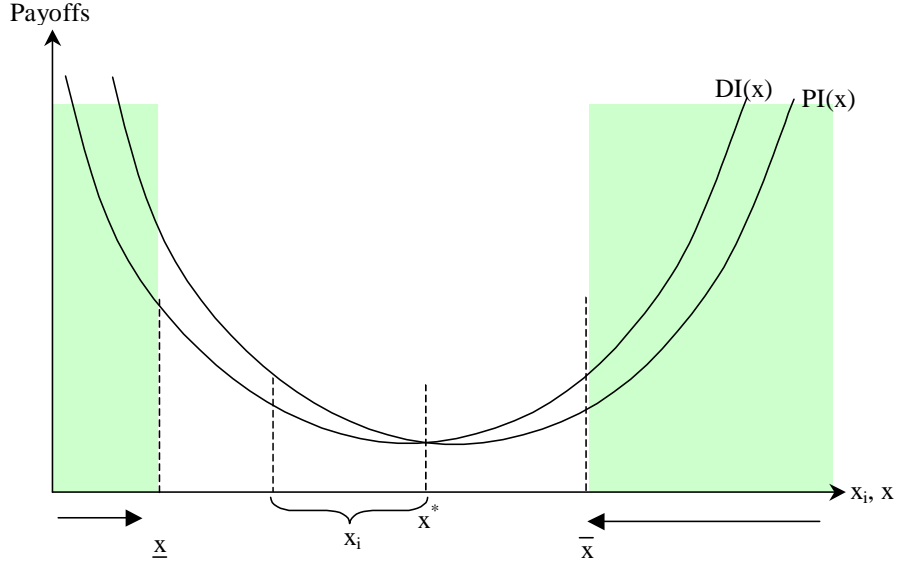


Figure (3)

By a similar argument, \bar{x} is defined as the upper bound of the investor with the largest realisation of ε . Hence, for a given value of fundamentals and private signals observed by investors, the presence of higher order beliefs leads to regions where it is strictly dominant to invest in DI because the expected payoffs are higher, and there are other regions where it is strictly dominant to invest in PI.

In this context of incomplete information, a Bayesian pure strategy for player i is a function $s_i : \mathbb{R} \rightarrow A_i$, and S_i is the set that contain all such strategies. A pure strategy profile is a vector $s = (s_1, s_2, \dots, s_N)$, where $s_i \in S_i$ for all i and equivalently define $s_{-i} = (s_1, s_2, \dots, s_{i-1}, s_{i+1}, \dots, s_N) \in S_{-i}$. A switching strategy is a Bayesian pure strategy s_i satisfying $\exists z_i$ s.t.

$$s_i(x_i) = \begin{cases} 1 & \text{if } x_i > z_i \\ 0 & \text{if } x_i < z_i \end{cases}$$

Let $s_i(\cdot; z_i)$ denote the switching strategy with switching threshold z_i .

In this incomplete information game, player i 's payoff will be characterized by his beliefs about his opponents strategies and about the true value of the fundamental. Given these noise structure, it is easy to see how players form beliefs. If investor i receive a signal x_i he will consider that the true value of the fundamental is normally distributed with mean x_i and standard deviation σ and he will consider that his opponent's signal x_j is normally distributed with mean x_i and standard deviation $\sqrt{2}\sigma$.

Therefore, in general, if player i is observing a signal x_i and is facing a strategy s_{-i} his expected net gain of choosing action 1 instead of action 0 can be written as

$$\Delta\Pi(s_{-i}, x | x_i) = \int_{-\infty}^{\infty} \int_{x_{-i}} \frac{1}{\sigma} \phi\left(\frac{x - x_i}{\sigma}\right) \Delta\pi(s_{-i}(x_{-i}), x) dF(x_{-i} | x_i) dx$$

Where dF denote the conditional joint density of other players' signals.

We will ask for an additional property:

A5 Single Crossing (SC). There exists a unique value x^* , of the exogenous variable such that if player i receive a signal $x_i = x^*$ and he believes that all other players are using a switching strategy with threshold x^* , the expected value of his payoffs when he chooses 0 or 1 are the same:

$$\int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - x^*}{\sigma}\right) \sum_n \binom{N-1}{n} \Delta\pi(n, x) dx = 0$$

$$\text{i.e. } \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - x^*}{\sigma}\right) \sum_{n=0}^{N-1} \binom{N-1}{n} ([q((n+1)k, x)k - \frac{\gamma}{2}(k+c)^2] - [(\bar{\pi}(x) + dnk, x)k - \frac{\theta}{2}k^2]) dx = 0$$

$$\int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - x^*}{\sigma}\right) \sum_{n=0}^{N-1} \binom{N-1}{n} ([q((n+1)k, x) - (\bar{\pi}(x) - d(nk, x))]k - \frac{\gamma}{2}(k+c)^2 + \frac{\theta}{2}k^2) dx = 0$$

$$[-\frac{\gamma}{2}(k+c)^2 + \frac{\theta}{2}k^2] \sum_{n=0}^{N-1} \binom{N-1}{n} + \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - x^*}{\sigma}\right) \sum_{n=0}^{N-1} \binom{N-1}{n} ([q((n+1)k, x) - (\bar{\pi}(x) - d(nk, x))]k) dx = 0$$

$$\int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x-x^*}{\sigma}\right) \sum_{n=0}^{N-1} [q((n+1)k, x) - (\bar{\pi}(x) + d(nk, x))] dx = \left(\frac{2^{N-1}}{k}\right) \left[\frac{\gamma}{2} (k+c)^2 - \frac{\theta}{2} k^2\right]$$

$$\int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x-x^*}{\sigma}\right) \sum_{n=0}^{N-1} [q((n+1)k, x) - (\bar{\pi}(x) + d(nk, x))] dx = 2^{N-1} \lambda$$

recall from the note in Appendix 5 that $\lambda = \frac{\gamma}{2k}(k+c)^2 - \frac{\theta}{2k}k^2$

Calling this game of incomplete information as $\Gamma(\sigma)$, let us define $BNE(\Gamma(\sigma))$ as the set of Bayesian Nash equilibria of $\Gamma(\sigma)$.

The main results of the paper proves that $\Gamma(\sigma)$ has a unique profile s^* , played in equilibrium $\forall \sigma > 0$, and in this profile every player will play a switching strategy $s_i(\cdot; x^*)$ with x^* according to assumption 5, A5

Theorem 1 Consider the game $\Gamma(\sigma)$. Under assumptions A1 to A5:

$\forall \sigma > 0$ there exists a unique strategy profile s^* surviving iterated elimination of strictly dominated strategies, where:

$$s_i^*(x_i; x^*) = \begin{cases} \mathbf{1} & \text{if } x_i > x^* \\ \mathbf{0} & \text{if } x_i < x^* \end{cases} \quad \forall i \text{ and } \underline{x} < x^* < \bar{x}$$

so that $BNE(\Gamma(\sigma)) = \{s^*\}$.

It is interestingly to note that even though there exist a unique symmetric equilibrium profile, conditional on the true value of the fundamental there will be a proportion of players choosing either DI or PI. For example if the realized value of the fundamental is x , then the proportion of players that will choose DI will be those who receive a signal greater than x^* . Hence, both DI and PI are equilibrium outcomes, based upon the private signal investors receive and due to their higher order belief and a relevant question is, given the realized state of the fundamental, what is the probability $p(\mu, x)$ that at least $\mu \leq N$ players will choose DI?

$$p(\mu, x) = \sum_{n \geq \mu} \binom{N}{n} \left[\Phi\left(\frac{x-x^*}{\sigma}\right) \right]^{N-n} \left[1 - \Phi\left(\frac{x-x^*}{\sigma}\right) \right]^n$$

5 Conclusions

This paper has shown that heterogeneity among foreign investors, due to asymmetric expectations about some fundamental variables that characterize the degree of transparency in the host country, can be exploited by rational agents for the determination of an equilibrium strategy. Depending on how noisy the economic environment is, agents will find it optimal to engage relatively more into FDI versus PI investment types.

This result has a clear-cut normative implication: Lower noise leads to higher FDI-, relative to PI-shares. Recent empirical contributions (discussed in Sections 1 and 2) suggest that investment flows stemming from FDI have a bigger positive impact on long term economic growth prospects. Governments of the host countries as well as the institutions financing investment projects to those countries should therefore place a great importance on the degree of transparency and its determinants.¹²

Further empirical work investigating the nature of transparency and the statistical significance of its underlying components (institutional framework, capital markets, and corporate governance transparency, ability of screening the financial soundness of foreign investors) is necessary.¹³ Two recent contributions by Lane and Milesi-Ferretti (2003 (a), 2003 (b)), suggest that it is unlikely that these components are time-invariant for a particular country or group of recipient countries. Countries may undergo different investment cycles, at times with larger (PI) FDI-shares, depending on which of the underlying components that co-determine a country's degree of transparency stand out over time.

Dynamic models which allow for repeated interactions among heterogeneous investors, may be more well suited to describe the investment cycles of a typical host country. Such a model

¹²As we already noted, this conclusion is also stressed by Goldstein and Razin. The recent policy advocated by the World Bank to increase the "accountability" of the host countries receiving FDI is a clear step in trying to "enforce" transparency. See for example, Kaufmann and Kraay (2002).

¹³Kaufmann and Kraay (2002) point to the practical difficulties in assessing a country's transparency on several dimensions.

is left for future work.¹⁴

¹⁴Giannitsarou and Toxvaerd (2003) focus on recursive (dynamic) global games.

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Appendix

The Case of Complete Information

■ *Note:*

From A4.1

$$[q(k, \bar{x})k - \frac{\gamma}{2}(k+c)^2] - [((\bar{\pi}(\bar{x}) + d(0, \bar{x}))k - \frac{\theta}{2}k^2)] = 0$$

$$(q(k, \bar{x}) - \bar{\pi}(\bar{x}) - d(0, \bar{x}))k - \frac{\gamma}{2}(k+c)^2 + \frac{\theta}{2}k^2 = 0$$

If $d(0, \bar{x}) = 0$

$$q(k, \bar{x}) - \bar{\pi}(\bar{x}) = \frac{\gamma}{2k}(k+c)^2 - \frac{\theta}{2k}k^2$$

$$\text{Define: } \frac{\gamma}{2k}(k+c)^2 - \frac{\theta}{2k}k^2 = \lambda > 0$$

From A4.2 we get

$$q(Nk, \underline{x}) - \bar{\pi}(\underline{x}) - d((N-1), \underline{x}) = \frac{\gamma}{2k}(k+c)^2 - \frac{\theta}{2k}k^2 = \lambda$$

Then, it must be true that:

$$q(k, \bar{x}) - \bar{\pi}(\bar{x}) = q(Nk, \underline{x}) - \bar{\pi}(\underline{x}) - d((N-1), \underline{x}). \blacksquare$$

Proof of Theorem 1

Proof of Theorem 1: (this proof follows a similar structure as in Harrison and Munoz (2003))

Denoting S_i^t the player i 's set of strategies that survives t rounds of deletion of interim strictly dominated strategies, the process of iterated elimination is defined recursively as follows: set $S_i^0 \equiv S_i$ and for all $t > 0$

$$S_i^t \equiv \left\{ \begin{array}{l} s_i \in S_i^{t-1} : \nexists s'_i \in S_i^{t-1} \text{ s.t. } \Pi(s'_i(x_i), s_{-i}, x | x_i) \geq \Pi(s_i(x_i), s_{-i}, x | x_i) \forall x_i \\ \text{and with strict inequality for some } x_i, \forall s_{-i} \in S_{-i}^{t-1} \end{array} \right\}$$

Consider a link formation game $G(\sigma)$. Under assumptions A1 to A5, we will argue by induction that set S_i^t satisfies:

$$S_i^t = \{s_i : s_i(x_i) = 0 \text{ if } x_i < \underline{x}^t \text{ and } s_i(x_i) = 1 \text{ if } x_i > \bar{x}^t\},$$

where \underline{x}_i and \bar{x}_i are defined recursively as

$$\bar{x}^t = \max \{x_i : \Delta\Pi((s_j(x_j; \bar{x}^{t-1}))_{j \neq i}, x \mid x_i) = 0\}$$

$$\underline{x}^t = \min \{x_i : \Delta\Pi((s_j(x_j; \underline{x}^{t-1}))_{j \neq i}, x \mid x_i) = 0\}$$

The first round of elimination is described in the following lemma.

Lemma: For all $i \exists \underline{x}^1 > \underline{x}$ and $\bar{x}^1 < \bar{x}$ s.t.

$$s_i \in S_i^1 \text{ iff } s_i(x_i) = \{0 \text{ if } x_i < \underline{x}^1 \text{ and } 1 \text{ if } x_i > \bar{x}^1\}$$

where

$$\bar{x}^1 = \max \{x_i : \Delta\Pi((s_j(x_j; \bar{x}))_{j \neq i}, x \mid x_i) = 0\}$$

$$\underline{x}^1 = \min \{x_i : \Delta\Pi((s_j(x_j; \underline{x}))_{j \neq i}, x \mid x_i) = 0\}$$

proof. Starting from the left: Player i (henceforth P_i) receive a signal $x_i = \underline{x}$, from A3 (Strategic Complementarities), if s_i is a best response to a profile where every player is choosing a switching strategy $s_j(\cdot; \underline{x}) \forall j \neq i$, it will be a best response to any $s_{-i} \in S_{-i}^0$. Then player i ' expected payoff difference between choosing action a_i rather than action 0 can be written as

$$\Delta\Pi(s_j(x_j; \underline{x}))_{j \neq i}, x \mid \underline{x} = \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - \underline{x}}{\sigma}\right) \int_{x_{-i}} \Delta\pi(s_j(x_j; \underline{x}))_{j \neq i}, x dF(x_{-i} \mid \underline{x}) dx$$

or equivalently by

$$\Delta\Pi(s_j(x_j; \underline{x}))_{j \neq i}, x \mid \underline{x} = \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - \underline{x}}{\sigma}\right) \sum_{a_{-i} \in A_{-i}} \Delta\pi(a_{-i}, x) \Pr(a_{-i} \mid (s_j(x_j; \underline{x}))_{j \neq i}, \underline{x}) dx$$

where in general $\Pr(a_{-i} \mid (s_j(x_j; \underline{x}))_{j \neq i}, x_i)$ represent player i ' beliefs about the action profile a_{-i} conditional on other players' strategy s_{-i} .

Now, since, $\forall \sigma > 0, \forall a_{-i} \in A_{-i}, \Pr(a_{-i} \mid (s_j(x_j; x_i))_{j \neq i}, x_i) = \frac{1}{2^{N-1}} > 0$, then

$$\Delta \Pi(s_j(x_j; \underline{x}))_{j \neq i}, x \mid \underline{x} = \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - \underline{x}}{\sigma}\right) \sum_{a_{-i} \in A_{-i}} \frac{1}{2^{N-1}} \Delta \pi(a_{-i}, x) dx$$

$$\Delta \Pi(s_j(x_j; \underline{x}))_{j \neq i}, x \mid \underline{x} = \frac{1}{2^{N-1}} \sum_{a_{-i} \in A_{-i}} \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - \underline{x}}{\sigma}\right) \Delta \pi(a_{-i}, x) dx$$

By assumptions A3 (Strategic Complementarities) and A4 (Indifferent values of the fundamental index) and the symmetry of ϕ , $\forall a_{-i} \neq (1, 1, \dots, 1)$, $\int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - \underline{x}}{\sigma}\right) \Delta \pi(a_{-i}, x) dx < 0$. Therefore P_i , upon receiving signal $x_i = \underline{x}$, will play action $a_i = 0$.

Now, if P_i receive a sufficiently high signal, the probability that he is facing a profile of actions where every other player is choosing action 1 is close to one, therefore his expected payoff will be strictly positive. i.e. if $x_i \gg \underline{x}$, then

$$\Delta \Pi(s_j(x_j; \underline{x}))_{j \neq i}, x \mid x_i = \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - x_i}{\sigma}\right) \sum_{a_{-i} \in A_{-i}} \Delta \pi(a_{-i}, x) \Pr(a_{-i} \mid (s_j(x_j; \underline{x}))_{j \neq i}, x_i) dx > 0$$

Given continuity of the expected utility function and using the *intermediate value theorem*:

$$\forall \sigma > 0, \exists \underline{x}^1 \text{ s.t. } \underline{x} < \underline{x}^1 \text{ where } \underline{x}^1 = \min \{x_i \mid \text{equation (2) holds}\}$$

$$\Delta \Pi((s_j(x_j; \underline{x}))_{j \neq i}, x \mid x_i) = \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - x_i}{\sigma}\right) \sum_{a_{-i} \in A_{-i}} \Delta \pi(a_{-i}, x) \Pr(a_{-i} \mid (s_j(x_j; \underline{x}))_{j \neq i}, x_i) dx = 0 \quad (2)$$

Starting from the right and using an equivalent argument we conclude that:

$$\forall \sigma > 0, \exists \bar{x}^1 \text{ s.t. } \bar{x} > \bar{x}^1 \text{ where } \bar{x}^1 = \max \{x_i \mid \text{equation (3) holds}\}$$

$$\Delta \Pi((s_j(x_j; \bar{x}))_{j \neq i}, x \mid x_i) = \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - x_i}{\sigma}\right) \sum_{a_{-i} \in A_{-i}} \Delta \pi(a_{-i}, x) \Pr(a_{-i} \mid (s_j(x_j; \bar{x}))_{j \neq i}, x_i) dx = 0$$

(3)

■ *Lemma:*

Repeating the process described in this lemma, it is easy to prove by induction that $\exists \underline{x}^t > \underline{x}^{t-1}$ and $\bar{x}^t < \bar{x}^{t-1}$ s.t.

$$S_i^t = \{s_i : s_i(x_i) = 0 \text{ if } x_i < \underline{x}^t \text{ and } s_i(x_i) = 1 \text{ if } x_i > \bar{x}^t\}$$

where

$$\bar{x}^t = \max \{x_i : \Delta\Pi((s_j(x_j; \bar{x}^{t-1}))_{j \neq i}, x \mid x_i) = 0\}$$

$$\underline{x}^t = \min \{x_i : \Delta\Pi((s_j(x_j; \underline{x}^{t-1}))_{j \neq i}, x \mid x_i) = 0\}$$

This process generates an increasing sequence $\{\underline{x}^t\}$ and a decreasing sequence $\{\bar{x}^t\}$. Let us suppose there exists limit points \underline{x}^∞ and \bar{x}^∞ , then from equation (2)

$$\int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - \underline{x}^\infty}{\sigma}\right) \sum_{a_{-i} \in A_{-i}} \Delta\pi(a_{-i}, x) \Pr(a_{-i} \mid (s_j(x_j; \underline{x}^\infty))_{j \neq i}, \underline{x}^\infty) dx = 0$$

Since $\Pr(a_{-i} \mid (s_j(x_j; \underline{x}^\infty))_{j \neq i}, \underline{x}^\infty) = \frac{1}{2^{N-1}}$, then

$$\Delta\Pi((s_j(x_j; \underline{x}))_{j \neq i}, x \mid \underline{x}^\infty) = \frac{1}{2^{N-1}} \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - \underline{x}^\infty}{\sigma}\right) \sum_{a_{-i} \in A_{-i}} \Delta\pi(a_{-i}, x) dx = 0 \quad (4)$$

Equivalently from equation 3, for the limit point \bar{x}^∞ we get

$$\Delta\Pi((s_j(x_j; \bar{x}^\infty))_{j \neq i}, x \mid \bar{x}^\infty) = \frac{1}{2^{N-1}} \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - \bar{x}^\infty}{\sigma}\right) \sum_{a_{-i} \in A_{-i}} \Delta\pi(a_{-i}, x) dx = 0 \quad (5)$$

recall that $n = \sum_{j \neq i} a_j$, then $n \in \{0, 1, \dots, N-1\}$, hence it is easy to check that $\sum_{a_{-i} \in A_{-i}} \Delta\pi(a_{-i}, \underline{x}) \Pr(a_{-i} \mid (s_j(x_j; z))_{j \neq i}, x_i) = \sum_n \binom{N}{n} \Delta\pi(n, x) \Pr(n \mid (s_j(x_j; z))_{j \neq i}, x_i)$ and in particular if $z = x_i$ we get

$$\sum_{a_{-i} \in A_{-i}} \Delta\pi(a_{-i}, x) = \sum_n \binom{N}{n} \Delta\pi(n, x)$$

plugging in equations 4 and 5

$$\Delta\Pi((s_j(x_j; \underline{x}^\infty))_{j \neq i}, x \mid \underline{x}^\infty) = \frac{1}{2^{N-1}} \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - \underline{x}^\infty}{\sigma}\right) \sum_n \binom{N-1}{n} \Delta\pi(n, x) dx = 0 \quad (6)$$

$$\Delta\Pi((s_j(x_j; \bar{x}^\infty))_{j \neq i}, x \mid \bar{x}^\infty) = \frac{1}{2^{N-1}} \int_{-\infty}^{\infty} \frac{1}{\sigma} \phi\left(\frac{x - \bar{x}^\infty}{\sigma}\right) \sum_n \binom{N-1}{n} \Delta\pi(n, x) dx = 0 \quad (7)$$

Finally, it is easy to see that equations (6) and (7) are the same, and from assumption

A5 $\underline{x}^\infty = \bar{x}^\infty = k^*$. Then $S^\infty = \bigcap_{t=0}^{\infty} S^t = \{(s_i(x_i; x^*))_{i=1}^N\}$ ■