Foreign Investment under Asymmetric Information when there exists a Market for Information*

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Abstract

We are interested in how much investors know about the country, sector or firm they invest in. Therefore we develop a model of a market for information and study the equilibrium quality of the traded information. The demand for information is derived from a moral hazard problem that capital owners face. The following assumptions are made concerning the market's supply side: a signal of higher quality is more costly to produce; once a signal is produced it can be supplied infinitely often; and there is free entry. In this setting, at most one information supplier produces a signal, the number of buyers has to exceed a critical number for a signal to be produced at all and the quality of the produced signal is strictly increasing in the number of buyers. We derive the implications for the equilibrium allocation of capital.

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1 Introduction

We are interested in how much investors know about the country, sector or firm they invest in. Investors that are less well informed than their potential contracting partners and therefore face a costly adverse selection or moral hazard problem have an incentive to reduce the degree of informational asymmetry by purchasing information. In the real world investment funds, banks and multinational firms purchase information from business information providers like Reuters, credit rating agencies like Moody's and country information providers like Economist Intelligence Unit. We develop a formal model of the market for information in order to study under which conditions information suppliers decide to produce information about a country, sector or firm and in order to derive the equilibrium *quality* of the produced information. We arrive at predictions concerning how well-informed investors are about different countries, sectors or firms. The implications for the equilibrium allocation of capital are derived. We focus on country-specific information. Extending the model to sector- or firm-specific information is straightforward.

In the model there are two countries: a small open economy and the rest of the world. The information available for purchase is a signal that announces the realization of the small open economy's productivity shock. The quality of the information is indexed by the probability that the signal announces the realization correctly. The demand for information is derived from a moral hazard problem à la Holmström (1979): A capital owner located in the rest of the world investing in the small open economy does not observe managerial effort, but does observe output of his firm and receives a signal. The Holmström (1979) setup is extended by allowing the principal to choose the quality of the signal before offering a contract. The optimal contract is derived and it is shown that the value of a signal is continuously differentiable and strictly increasing in the quality of a signal. The supply side of the market for information is characterized by the following assumptions: The cost of producing a signal is continuously differentiable and strictly increasing in the quality of a signal; once a signal is produced it can be supplied infinitely often; and there is free entry. We argue below that modeling the supply side of the market for information in this way is novel and a good description of reality. We analyze two cases: Firstly, investors located in the rest of the world each allocate one unit of capital and cannot resell or share their signal.

Secondly, investors located in the rest of the world can avoid duplication of the purchase of information by creating an intermediary.

Consider the first case. In equilibrium at most one information supplier produces a signal and the foreign owned capital stock has to exceed a critical level for a signal to be produced at all. Most importantly, the quality of the produced signal is strictly increasing in the foreign owned capital stock. Hence, a complementarity among foreign capital arises. Nevertheless, the equilibrium allocation of capital is unique. The reason is that, by assumption, information suppliers move first and anticipate the allocation of capital that results from any possible outcome of their entry game. Consider the second case. Somewhat surprising, we find that the quality of the produced signal is the same as in the first case. The reason is that in both cases the quality of the produced signal is an element of the set of efficient signal qualities. We also show that a reduction in the cost of transmitting a signal increases the quality of the produced signal. Turning to policy implications, we show that taxing labor and subsidizing foreign owned capital can be a welfare improving policy.

Many economists have argued that informational asymmetries between non-residents and residents are an important reason for international capital immobility (e.g. Gertler and Rogoff (1990), Gordon and Bovenberg (1996), Lane (1999)). In this literature the information system is exogenous. It is not explained which countries suffer from a large degree of informational asymmetry. This is a problem, since a policy maker concerned about the lack of capital flows to a given country would like to know whether the cause is asymmetric information, limited enforcement or another capital market imperfection. The model developed below provides some guidance in identifying the countries that face a large degree of informational asymmetry.

The paper is organized as follows. In Section 2 the existing literature on information acquisition and markets for information is reviewed. In Section 3 the model is presented. In Section 4 the optimal principal-agent contract is derived. In Section 5 equilibrium on the market for information and the equilibrium allocation of capital are derived. Section 6 contains a discussion. Section 7 concludes.

2 Related literature

There exists an extensive literature on costly information acquisition, in which the cost of acquiring information is exogenous. Firstly, Hirshleifer (1971) shows that in a simple exchange economy with uncertainty and trade in state contingent commodities there might be a private incentive for agents to acquire information, although the social value of information is zero or even negative. Secondly, Wilson (1975) shows that if a firm can acquire costly information which increases productivity independent of the scale of production then the optimal scale of production is unbounded, precluding the existence of a competitive equilibrium. Moreover, if the value of information per unit scale is increasing and strictly concave in information quality and the cost of acquiring information is increasing and convex in information quality then a larger scale of production justifies the acquisition of information of higher quality. Thirdly, Grossman (1976) points out that a stock market equilibrium with costly information acquisition may not exist if stock prices reflect acquired information too strongly. In the subsequent noisy rational expectations models (e.g. Grossman and Stiglitz (1980) and Hellwig (1980)) traders use their informative signals and the current price of the risky asset in order to form their expectation of the return on the risky asset, but a fully revealing price is avoided by assuming a random supply of the risky asset. In this context, Grossman and Stiglitz (1980) and Barlevy and Veronesi (2000) study how many traders decide to acquire costly information and to which extent their information is transmitted via the current price of the risky asset. Verrecchia (1982) extends the analysis to traders that differ in their degree of risk aversion and can choose among signals with different precision. Fourthly, Crémer and Khalil (1992) and Crémer, Khalil and Rochet (1998a, 1998b) show that giving the agent in a principal-agent model the possibility to gather costly information can lead to an optimal contract that is different from the standard uninformed agent contract (standard informed agent contract) even when the agent does not gather information (does gather information) in equilibrium. In contrast to the papers cited above, in the model developed below the principal in a principal-agent model can acquire costly information. The principal values information, because it allows him to write a more efficient incentive-compatible contract. It is shown that agency costs are strictly decreasing in a measure of the quality of the acquired information. More importantly, in the model developed below the supply side of the market for information is explicitly modelled and therefore the cost of acquiring information is endogenous.

Admati and Pfleiderer (1986, 1990) explicitly model the supply side of the market for information in the context of a noisy rational expectations model. They study how a monopolistic seller of information that is endowed with an informative signal optimally sells the signal to traders. The seller faces the problem that prices transmit information. In Admati and Pfleiderer (1986) it is shown that for some parameter values adding noise to the signal increases profits and adding personalized noise increases profits even more. In Admati and Pfleiderer (1990) it is shown that whether the seller prefers to sell the signal directly or prefers to sell shares in a portfolio that is created on the basis of the information depends on the extent to which prices transmit information under direct sale and the heterogeneity of traders. In contrast, in the model developed below prices do not transmit information, since the only action depending on the signal is the principal's unobservable ex-post payment to the agent. The focus instead is to derive price and quality of the traded information when information suppliers need to *produce* information before supplying it.

Some aspects of information production have been analyzed in the literature on financial intermediation, e.g. the problem of how to appropriate the returns from information production and the problem of information reliability when investors cannot evaluate the quality of information. Leland and Pyle (1977) suggested that financial intermediation may be a response to asymmetric information and the desire to economize on the costs of information production. Campbell and Kracaw (1980) show that the appropriability problem is solved if side payments that undervalued firms are willing to pay to induce information production exceed side payments that overvalued firms are willing to pay to deter information production. Thakor (1982) shows that the appropriability problem is also solved if there exists a service that information producers can sell to firms and that acts as a costly signal of a firm's value. In Ramakrishnan and Thakor (1984) each firm that gains from being correctly identified pays a risk-averse information producer to produce the information and the reliability problem is solved by making the compensation contingent on a noisy ex-post indicator of information quality. It is shown that agency costs can be reduced by contracting with a diversified information producer, in case the latter has access to costless internal monitoring. In Diamond (1984) risk-neutral investors can respond to the fact that they do not observe the realized return of risk-neutral entrepreneurs by offering a debt contract with bankruptcy penalty, by costly individual monitoring or by delegating the monitoring task to a risk-neutral intermediary. Delegated monitoring avoids duplication of the monitoring cost, but the intermediary needs to be given the right incentives in form of a debt contract with bankruptcy penalty. It is shown that the more diversified the intermediary's portfolio of entrepreneurs, the less likely is a bad outcome and the lower is the cost of delegation. Another aspect of information production that has received attention in the literature on financial intermediation is reusability of information. Chan, Greenbaum and Thakor (1986) show that if screening has a value in the first period that is strictly increasing and concave in screening intensity and screening costs are strictly increasing and strictly convex in screening intensity then high durability of information over time implies that banks screen more intensively. In the model developed below reusability of information plays an important role, but information is reusable across space instead of over time. Furthermore, no assumptions are made concerning the concavity of the value of information or the convexity of the cost of producing information.

3 Model

The model consists of two countries: a small open economy and the rest of the world. Capital is perfectly mobile between the two countries. Labor is only mobile within the small open economy.

3.1 Small open economy

The small open economy consists of a large number of firms. A firm is either owned by domestic investors or by foreign investors. If a firm is owned by domestic investors then the production function is given by

$$Y_i = F\left(K_i, L_i\right)\Theta_i, \tag{1}$$

where Y_i is output, K_i is capital stock and L_i is labor input of firm i. $F : \mathsf{R}_+^2 \to \mathsf{R}$ satisfies the standard properties of a neoclassical production function.[1] The productivity parameter of the firm, Θ_i, only depends on the aggregate productivity shock, ε,

$$\Theta_i = \begin{cases} \Theta_H & \text{if } \varepsilon = \varepsilon_H, \\ \Theta_L & \text{if } \varepsilon = \varepsilon_L \end{cases} \tag{2}$$

where $\Theta_H > \Theta_L > 0$ and ε has a binomial distribution with $\Pr\{\varepsilon = \varepsilon_H\} = q$ and $\Pr\{\varepsilon = \varepsilon_L\} = 1 - q$ with $q \in (0, 1)$. If a firm is owned by foreign investors then the production function is given by

$$Y_j = F(K_j, L_j)\,\Theta_j. \tag{3}$$

We assume that each foreign investor has to open his own firm. If the foreign investor who owns firm j does not hire a manager then $\Theta_j = 0$, i.e. a foreign investor needs to hire a manager in order to produce output. If the foreign investor who owns firm j does hire a manager then the productivity parameter of the firm, Θ_j, depends on the aggregate productivity shock, ε, as well as on effort exerted by the manager, e_j,

$$\Theta_j = \begin{cases} \Theta_H & \text{if } \varepsilon = \varepsilon_H \text{ and } e_j = e_H. \\ \Theta_L & \text{if } \varepsilon = \varepsilon_L \text{ or } e_j = e_L \end{cases} \tag{4}$$

Equation (4) states that high productivity of the firm can only occur when the manager exerts high effort. Hence, a foreign investor would like his manager to exert high effort.

The economy is populated by a large number of managers. Managers dislike exerting high effort, are risk averse and have an outside option. Formally, a manager maximizes expected utility and a manager's Bernoulli utility function is given by

$$U(x, e) = \begin{cases} u(x) - v(e) & \text{if hired} \\ \bar{U} & \text{otherwise} \end{cases}, \tag{5}$$

where x is the payment to the manager and $e \in \{e_L, e_H\}$ is the effort he exerts. $v(e_H) > v(e_L) > 0$, $u : \mathsf{R} \to \mathsf{R}$ is a strictly increasing, strictly concave and twice continuously

[1] F satisfies the following properties: F is twice continuously differentiable in K and L on the interior of its domain with $\frac{\partial F(K,L)}{\partial K} > 0$, $\frac{\partial F(K,L)}{\partial L} > 0$, $\frac{\partial^2 F(K,L)}{\partial^2 K} < 0$ and $\frac{\partial^2 F(K,L)}{\partial^2 L} < 0$. Furthermore, F is homogeneous of degree 1 in K and L. Finally, $\lim_{K \to 0}\left(\frac{\partial F(K,L)}{\partial K}\right) = \infty$ and $\lim_{K \to \infty}\left(\frac{\partial F(K,L)}{\partial K}\right) = 0$.

differentiable function and $\bar{U} \geq 0$. The fact that the manager dislikes exerting high effort implies that a conflict of interest arises between the foreign investor (principal) and the manager (agent). The fact that the manager is risk averse and that he has an outside option implies that the manager has to be compensated for any exposure to risk.

A moral hazard problem arises, because we assume that the foreign investor (principal) cannot directly observe effort exerted by the manager (agent). We assume the following information structure: A foreign investor only observes productivity of his firm (since he observes factor inputs and output of his firm) and he receives a signal of the aggregate productivity shock. The signal is provided by information suppliers as specified below. The signal has the following properties: $\phi_j \in \{\varepsilon_L, \varepsilon_H\}$ with $\Pr\left\{\phi_j = \varepsilon\right\} = 0.5 + z_j$ and $\Pr\left\{\phi_j \neq \varepsilon\right\} = 0.5 - z_j$. In words, the signal announces the realization of the aggregate productivity shock correctly with probability 0.5 plus z_j. Hence, $z_j \in [0, 0.5]$ measures the quality of the signal. We assume that the quality of the foreign investor's signal is known to the manager.

The economy is populated by L workers. Each worker is endowed with one unit of labor that he can supply to a domestic firm and a units of wealth of which he can invest $a_s \in [0, a]$ units domestically and $a_w = a - a_s$ units abroad. Workers maximize expected utility. The Bernoulli utility function of a worker $\vartheta : \mathsf{R} \rightarrow \mathsf{R}$ is strictly increasing, strictly concave and twice differentiable in the worker's consumption.

The domestic capital market and labor market are perfectly competitive.

3.2 Rest of the world

The rate of return in the rest of the world $R_w > 0$ is exogenous and constant.

The rest of the world is populated by a large number of risk-neutral investors. Each investor allocates one unit such as to maximize the expected return. An investor investing in the small open economy needs to hire a manager in order to produce output and can buy the right to receive a signal of quality $z_j \in [0, 0.5]$. The investor can buy only one signal and cannot resell or share the signal. Hence, investment in the small open economy earns a net rate of return

$$R_j^F = R_j - x_j - P(z_j), \tag{6}$$

where R_j is the marginal product of capital of firm j, x_j is the payment to the manager and $P(z_j)$ is the price of a signal of quality z_j.[2]

There exist $N \geq 2$ potential information suppliers. Each information supplier can produce a signal of quality $z \in [0, 0.5]$ at cost $C(z)$. The function $C : [0, 0.5] \to \mathsf{R}$ is strictly increasing on $[0, 0.5]$ and continuously differentiable on $(0, 0.5)$. Hence, producing a signal of higher quality is more costly. An information supplier that has produced a signal can supply the signal infinitely often. Hence, $C(z)$ is a fixed cost. Transmitting the signal to a buyer may be associated with a cost $c(z) = c \geq 0$ for all $z \in (0, 0.5]$. We assume $C(0) = 0$ and $c(0) = 0$ so that we can interpret producing and transmitting a signal of quality $z = 0$ as not producing a signal at all. The market for information is characterized by free entry with the following entry process: All information suppliers $n = 1, ..., N$ decide simultaneously upon $(z_n, P(z_n))$.[3]

3.3 Timing

The timing is as follows: First of all, information suppliers choose simultaneously the quality of the signal that they produce and the price of the signal. Secondly, investors decide on the allocation of capital, decide whether to buy a signal and choose the quality of the signal.

[2] We follow Gertler and Rogoff (1990) in the way we model foreign investors. Investors located in the rest of the world investing in the small open economy own the firm and design the incentive contract for the manager. They invest in order to take advantage of a high return to capital. Hence, we abstract from other motives for investing in a country, e.g. economies of multiplant production due to knowledge capital and locational advantages due to trade barriers or transport costs. These are analyzed in the literature on direct foreign investment. See Markusen (1995) for a review.

[3] We think this corresponds well with the market for business information in reality. The biggest supplier of business information is Reuters. However, other information suppliers like AFP could enter the market for business information any time. Reuters offers certain products at a certain price. Buying one of these products gives the buyer the right to receive news once news arrives. News of higher quality is more costly to produce. The cost of producing news is independent of how often the news is sold, while delivering the news might be associated with a cost per user.

Thirdly, investors located in the rest of the world that invest in the small open economy design a contract and propose it on a take-it-or-leave-it basis to a manager. Managers that accept a contract choose an effort level. Subsequently, the aggregate productivity shock is drawn and foreign investors receive their signal. Finally, managers hire labor in a profit maximizing way, production takes place and managers receives a payment according to the payment scheme specified in their contract.

4 Optimal principal-agent contract

We solve the model backwards. In this section we derive the optimal contract that an investor located in the rest of the world offers a manager, for a given quality of the signal $z \in [0, 0.5)$. Building on the results of this section the equilibrium quality of the signal will be derived in the next section.

For the moment it will be assumed that a foreign investor always prefers a contract that induces his manager to exert high effort to a contract that induces low effort. This is the interesting case. The assumption is relaxed later. The foreign investor cannot observe managerial effort. Therefore the best the foreign investor can do in order to induce his manager to exert high effort is to offer a contract in which the payment depends on the realization of the firm's productivity, Θ_j, and the realization of the signal, ϕ_j.[4] In the following we drop the subscript j. The foreign investor can identify and verify four different states of the world: $(\Theta, \phi) \in \{(\Theta_H, \varepsilon_H), (\Theta_H, \varepsilon_L), (\Theta_L, \varepsilon_L), (\Theta_L, \varepsilon_H)\}$. A contract is therefore a vector $(x_{HH}, x_{HL}, x_{LL}, x_{LH})$. The probability distribution over these four different events depends on effort exerted by the manager and the quality of the signal

$$\begin{pmatrix} \pi_{HH,e_H} \\ \pi_{HL,e_H} \\ \pi_{LL,e_H} \\ \pi_{LH,e_H} \end{pmatrix} = \begin{pmatrix} q\,(0.5+z) \\ q\,(0.5-z) \\ (1-q)\,(0.5+z) \\ (1-q)\,(0.5-z) \end{pmatrix} \tag{7}$$

[4] Recall that we have assumed that a foreign investor only observes the productivity of his firm. If a foreign investor could also observe and verify the productivity of other firms then he could and should condition the payment on these variables as well. See Holmström (1982) and Acemoglu and Zilibotti (1999).

$$\begin{pmatrix} \pi_{HH,e_L} \\ \pi_{HL,e_L} \\ \pi_{LL,e_L} \\ \pi_{LH,e_L} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ q(0.5-z)+(1-q)(0.5+z) \\ q(0.5+z)+(1-q)(0.5-z) \end{pmatrix}, \tag{8}$$

where π_{HH,e_H} is the probability of event $(\Theta_H, \varepsilon_H)$ when the manager has exerted high effort.[5]

In order to design the optimal contract, the foreign investor solves the following minimization problem

$$\chi(z) \equiv \min_{(x_{HH},x_{HL},x_{LL},x_{LH})\in \mathsf{R}^4} E[x|e_H] \quad s.t. \tag{9}$$

$$E[u(x)-v(e)|e_H] \geq \bar{U} \tag{10}$$

$$E[u(x)-v(e)|e_H] \geq E[u(x)-v(e)|e_L]. \tag{11}$$

The foreign investor minimizes the expected payment to the manager subject to the participation constraint and the incentive-compatibility constraint. The participation constraint has to be satisfied for the manager to accept the contract. The incentive-compatibility constraint has to be satisfied for the manager to choose high effort instead of low effort. The conditional expectation of the foreign investor and the manager are taken with respect to the true conditional probability distribution given by equation (7) and (8).[6]

A solution to this minimization problem exists. The proof is in Appendix 1. Let γ denote the Lagrange multiplier of the participation constraint. Let μ denote the Lagrange

[5]Equation (7) is derived in the following way: $\pi_{HH,e_H} = \Pr\{\Theta = \Theta_H \cap \phi = \varepsilon_H|e_H\} = \Pr\{\varepsilon = \varepsilon_H \cap \phi = \varepsilon_H|e_H\} = \Pr\{\varepsilon = \varepsilon_H \cap \phi = \varepsilon_H\} = \Pr\{\varepsilon = \varepsilon_H\}\Pr\{\phi = \varepsilon_H|\varepsilon = \varepsilon_H\} = q(0.5+z)$. The second equality follows from equation (4). The fourth equality follows from Bayes' rule.

Equation (8) is derived in the following way: $\pi_{LL,e_L} = \Pr\{\Theta = \Theta_L \cap \phi = \varepsilon_L|e_L\} = \Pr\{\phi = \varepsilon_L|e_L\} = \Pr\{\phi = \varepsilon_L\} = \Pr\{\varepsilon = \varepsilon_H\}\Pr\{\phi = \varepsilon_L|\varepsilon = \varepsilon_H\} + \Pr\{\varepsilon = \varepsilon_L\}\Pr\{\phi = \varepsilon_L|\varepsilon = \varepsilon_L\} = q(0.5-z) + (1-q)(0.5+z)$. The second equality follows again from equation (4).

[6]Recall that we have assumed that the quality of the foreign investor's signal is known to the manager. This is a strong assumption, since the foreign investor *chooses* the quality of the signal. One way to interpret the assumption is that either the information supplier or the foreign investor can communicate the quality of the signal in a credible way to the manager.

multiplier of the incentive-compatibility constraint. Let $\varphi(.)$ denote the inverse function of $u'(.)$.[7] The following conditions are necessary and sufficient for a minimum

$$x_{HH} = \varphi\left(\frac{1}{\gamma+\mu}\right) \tag{12}$$

$$x_{HL} = \varphi\left(\frac{1}{\gamma+\mu}\right) \tag{13}$$

$$x_{LL} = \varphi\left(\frac{1}{\gamma-\mu\frac{q(0.5-z)}{(1-q)(0.5+z)}}\right) \tag{14}$$

$$x_{LH} = \varphi\left(\frac{1}{\gamma-\mu\frac{q(0.5+z)}{(1-q)(0.5-z)}}\right) \tag{15}$$

$$E\left[u(x)-v(e)\,|e_H\right] = \bar{U} \tag{16}$$

$$E\left[u(x)-v(e)\,|e_H\right] = E\left[u(x)-v(e)\,|e_L\right], \tag{17}$$

where $\gamma > 0$ and $\mu > 0$. The proof is in Appendix 2.

The optimal contract has a number of important properties: First of all, $x_{HH} = x_{HL} > x_{LL} \geq x_{LH}$, i.e. the optimal contract is a payment that depends on the state of the world. This is a common feature of moral hazard models. The cheapest way to satisfy the participation constraint is to offer the agent a fixed payment (first-best risk sharing), but the incentive-compatibility constraint requires offering the agent a payment that depends on the state of the world. The optimal contract optimally trades off risk sharing benefits and incentive creation. Secondly, if $z > 0$ then $x_{LL} > x_{LH}$, i.e. if the signal ϕ conveys information about the aggregate productivity shock then the foreign investor conditions the payment on the realization of the signal. This result is not surprising. Holmström (1979) has shown in a general principal-agent setup that the principal conditions the payment on an additional signal as long as the additional signal conveys additional information about the hidden action of the agent in states of the world of positive probability measure. In our model the signal ϕ conveys additional information about the effort choice of the manager when productivity of the firm is low. Thirdly, the expected payment to the manager

[7] $u'(.)$ is a continuously differentiable, strictly decreasing function for all $x \in \mathsf{R}$. It follows from the Inverse Function Theorem that $u'(.)$ is invertible for all $x \in \mathsf{R}$ and that its inverse function $\varphi(.)$ is a continuously differentiable, strictly decreasing function for all $u'(x) \in (u'(\infty), u'(-\infty))$.

associated with the optimal contract is given by $\chi(z)$. This expected payment is strictly decreasing in the quality of the signal. Thus the principal strictly prefers a signal of higher quality. This is the main result of this section.

Lemma 1 *The expected payment to the manager associated with the optimal contract, $\chi(z)$, is strictly decreasing in the quality of the signal, z.*

Proof. See Appendix 3. ■

In the next section we will also need the following differentiability result.

Lemma 2 *The expected payment to the manager associated with the optimal contract, $\chi(z)$, is continuously differentiable in the quality of the signal, z, for all $z \in (0, 0.5)$.*

Proof. See Appendix 4. ■

Note that, for the principal, the value of a signal of quality z equals $\chi(0) - \chi(z)$. Finally, if $z = 0.5$ then the moral hazard problem disappears. The foreign investor can observe managerial effort. Therefore the optimal contract is a fixed payment that satisfies the participation constraint with equality

$$x_{z=0.5} = u^{-1}\left(\bar{U} + v(e_H)\right). \tag{18}$$

5 Equilibrium

In this section we derive equilibrium on the market for information, characterized by the number of firms producing a signal as well as quality and price of the produced signal. Furthermore, we derive equilibrium on the labor market and equilibrium on the capital market. The easiest way to derive equilibrium is to proceed in two steps. In Section 5.1 we derive equilibrium conditions that have to be satisfied for any given stock of foreign capital invested in the small open economy, K^F. In Section 5.2 we derive the equilibrium stock of foreign capital invested in the small open economy, K^{F*}.

5.1 Arbitrary K^F

Equilibrium on the market for information requires that the following two conditions are satisfied.

Proposition 1 $\{(z_1, P(z_1)), ..., (z_N, P(z_N))\}$ *is a Nash equilibrium of the information suppliers' entry game only if*

1. *One information supplier produces a signal of quality*

$$z^* \in \Gamma\left(K^F\right) \equiv \arg\min_{z\in[0,0.5]} \left(\chi(z) + \frac{C(z)}{K^F} + c(z)\right).$$

   All other information suppliers produce a signal of quality $z = 0$.

2. *The price quoted for a signal of quality $z^* > 0$ is*

$$P(z^*) = \frac{C(z^*)}{K^F} + c(z^*).$$

Proof. See Appendix 5. ■

The set $\Gamma\left(K^F\right)$ is the set of signal qualities that are efficient for a given stock of foreign capital invested in the small open economy.[8] Each element minimizes the sum of total expected payment to managers, $\chi(z)K^F$, and total costs of signal production and transmission, $C(z) + c(z)K^F$. Proposition 1 contains a result concerning the number of firms producing a signal. If $\Gamma\left(K^F\right)$ is non-empty and $0 \notin \Gamma\left(K^F\right)$ then exactly one information supplier produces a signal and all other information suppliers produce no signal.[9] If $0 \in \Gamma\left(K^F\right)$ and $\Gamma\left(K^F\right)$ is single valued then all information suppliers produce no signal. If $0 \in \Gamma\left(K^F\right)$ and $\Gamma\left(K^F\right)$ contains another element then both cases mentioned above are possible. The result follows from the assumption that $C(z)$ is a strictly positive fixed cost for all $z > 0$ and the assumption that there is free entry. Proposition 1 also contains a result concerning the quality of the produced signal. The quality of the produced signal

[8] When we say efficient we mean of course constrained efficient, since the first best solution is only attained when foreign investors directly observe managerial effort.

[9] Producing a signal of quality $z = 0$ can be interpreted as producing no signal, since costs of producing such a signal are zero and demand is zero.

has to be an element of the set of efficient signal qualities, $\Gamma\left(K^F\right)$. This again follows from free entry. Finally, Proposition 1 contains a result concerning the quoted price of the signal. A signal of quality $z^* > 0$ has to be offered at a price such that profits are zero. This also follows from free entry. Note that if a signal of quality $z^* > 0$ is offered at a price $P(z^*)$ then all foreign investors investing in the small open economy buy the signal, since $\chi(z^*) + P(z^*) < \chi(0)$ if $0 \notin \Gamma\left(K^F\right)$ and $\chi(z^*) + P(z^*) = \chi(0)$ if $0 \in \Gamma\left(K^F\right)$. Furthermore, note that K^F only appears in Proposition 1, because K^F equals the number of potential buyers of a signal. The latter is due to the assumption that each foreign investor only allocates one unit and that foreign investors cannot resell or share a signal. Hence, by assumption foreign investors cannot avoid the duplication of the purchase of information. In Section 6 we also analyze the other extreme that investors located in the rest of the world can completely avoid duplication of the purchase of information by creating, without cost, an intermediary specialized on investment in the small open economy. Somewhat surprising we will find that results are the same.

In the following we analyze how the set of efficient signal qualities, $\Gamma\left(K^F\right)$, depends on the stock of foreign capital invested in the small open economy, i.e. on the number of potential buyers.

Proposition 2 *If $c < \chi(0) - \chi(0.5)$ then there exists a $\hat{K}^F > 0$ such that $0 \in \Gamma\left(K^F\right)$ and $\Gamma\left(K^F\right)$ is single valued for all $K^F < \hat{K}^F$ whereas $0 \notin \Gamma\left(K^F\right)$ for all $K^F > \hat{K}^F$.*

Proof. See Appendix 6. ■

Proposition 2 follows from the first result concerning the value of a signal ($\chi(z)$ is strictly decreasing in z) and the assumptions concerning the cost function of producing a signal ($C(z) > 0$ for all $z > 0$ and $C(z)$ is a fixed cost).

Proposition 3 *Let $z_1 \in \Gamma\left(K_1^F\right)$ and $z_2 \in \Gamma\left(K_2^F\right)$. Suppose $z_1 \in (0, 0.5)$. Then $K_2^F > K_1^F$ implies $z_2 > z_1$.*

Proof. See Appendix 7. ■

Proposition 3 follows from the second result concerning the value of a signal ($\chi(z)$ is continuously differentiable on the interior of its domain) and the assumptions concerning the cost function ($C(z)$ is a fixed cost, $C'(z) > 0$ and $C(z)$ is continuously differentiable on the interior of its domain) in combination with a general strict monotonicity theorem due to Edlin and Shannon (1998). Proposition 1, 2 and 3 immediately imply the following results.

Corollary 1 *The foreign owned capital stock has to exceed a critical level for a signal to be produced. Once the quality of the produced signal is an element of the set* $(0, 0.5)$ *then a strict increase in the foreign owned capital stock leads to a strict increase in the quality of the produced signal.*

Hence, the model predicts that, in the presence of a market for information, foreign investors investing in a country with a large foreign owned capital stock (e.g. Malaysia) purchase information of high quality and are well informed whereas foreign investors investing in a country with a small foreign owned capital stock (e.g. Morocco) purchase information of low quality and are less well informed.

Corollary 2 *If the quality of the produced signal is an element of the set* $(0, 0.5]$ *then a strict increase in the foreign owned capital stock leads to a strict decrease in agency costs.*

Define agency costs as $\tau\left(K^F\right) = \chi(0) - \chi(0.5)$ if $z^* = 0$ and $\tau\left(K^F\right) = \chi(z^*) + P(z^*) - \chi(0.5)$ if $z^* > 0$. Recall that $\chi(0.5)$ is the expected payment to the manager in the absence of an informational asymmetry. It follows from Proposition 1 that if $z^* \in (0, 0.5]$ then the price at which a given signal is offered is strictly lower when the stock of foreign capital is strictly higher. Hence, agency costs must be strictly lower. This effect is amplified by the fact that the quality of the produced signal increases as long as $z^* \in (0, 0.5)$.

It seems important to emphasize that all results in this section only require monotonicity and differentiability of the value of information and the cost of producing information. Concavity of the value of information or convexity of the cost of producing information are not required.

5.2 Equilibrium K^F

We now derive the equilibrium allocation of capital. Although a complementarity among foreign capital arises (quality and price of the produced signal depend on the foreign owned capital stock), the equilibrium allocation of capital is unique. No coordination problem arises. The reason is that, by assumption, information suppliers move first and anticipate the allocation of capital that results from any possible outcome of their entry game.

The first step towards deriving capital market equilibrium is to characterize labor market equilibrium. Labor is perfectly mobile within the small open economy. Therefore all firms in the small open economy have to pay the same wage w. Firms maximize profits and take the wage w as given. Thus

$$w = \frac{\partial F(K_i, L_i)}{\partial L_i}\Theta_i = \frac{\partial F(K_j, L_j)}{\partial L_j}\Theta_j, \tag{19}$$

where L_i and L_j are the labor demand of a domestic owned firm and a foreign owned firm respectively. As in Section 4 we assume that a foreign owner always prefers a contract that induces high effort. (The assumption is relaxed later.) Therefore $\Theta_i = \Theta_j$. Equation (19), $\Theta_i = \Theta_j$ and constant-returns-to-scale imply

$$\frac{K_i}{L_i} = \frac{K_j}{L_j} = \frac{K}{L}. \tag{20}$$

The next step is to characterize capital market equilibrium. The aggregate capital stock invested in the small open economy, K, equals the sum of domestic owned capital stock, K^H, and foreign owned capital stock, K^F. The domestic owned capital stock is the amount that workers invest in the small open economy. Each worker is endowed with a units of wealth of which he can invest $a_s \in [0, a]$ units domestically, earning a risky rate of return $R_i = \frac{\partial F(K_i, L_i)}{\partial K_i}\Theta_i$, and $a_w = a - a_s$ units abroad, earning a risk-less rate of return R_w. The optimal portfolio depends on the aggregate capital stock invested in the small open economy, K, since by equation (20) the distribution of the worker's wage and the distribution of the risky rate of return depend on K.

Proposition 4 *A worker's optimal portfolio has the following properties*:

1. $a_s = \psi(k)$ *where* $k = \frac{K}{L}$ *and* ψ *is a continuous function on* $\mathbb{R}_+$.

2. ψ *has a unique fixed point* $k_f = \psi(k_f)$. $k_f \in [0, a]$.

3. ψ *is non-increasing at* $k = k_f$.

Proof. See Appendix 8. ■

Define $K_f \equiv Lk_f$. Proposition 4 implies that

$$K^H = L\psi\left(\frac{K}{L}\right), \tag{21}$$

with $K^H = K$ if $K = K_f$, $K^H > K$ if $K < K_f$ and $K^H < K$ if $K > K_f$. Hence, in the case of autarchy $K = K_f$.

Investors located in the rest of the world invest in the small open economy as long as

$$E\left[R_j - x_j - P\left(z_j\right)\right] \geq R_w. \tag{22}$$

Again we assume that a foreign owner always prefers a contract that induces high effort. (The assumption is relaxed later.) This implies that a foreign owner buys a signal of quality z^* and offers the contract derived in Section 4. Equation (22) becomes

$$\frac{\partial F\left(K_j, L_j\right)}{\partial K_j}\bar{\Theta} \geq R_w + \chi\left(0.5\right) + \tau\left(K^F\right), \tag{23}$$

where $\bar{\Theta} = q\Theta_H + (1-q)\,\Theta_L$. The expected marginal product of capital (left-hand side of equation (23)) is strictly decreasing in K and approaches zero as K goes to infinity. This follows from equation (20) and the assumptions concerning the production function. A foreign owner's costs associated with investment in the small open economy (right-hand side of equation (23)) also depend on K, since $K^F = K - L\psi\left(\frac{K}{L}\right)$. As long as $K^F < \hat{K}^F$ no signal is produced and agency costs are constant. Once $K^F > \hat{K}^F$ a signal is produced and agency costs are strictly decreasing in the foreign owned capital stock. See Figure 1.

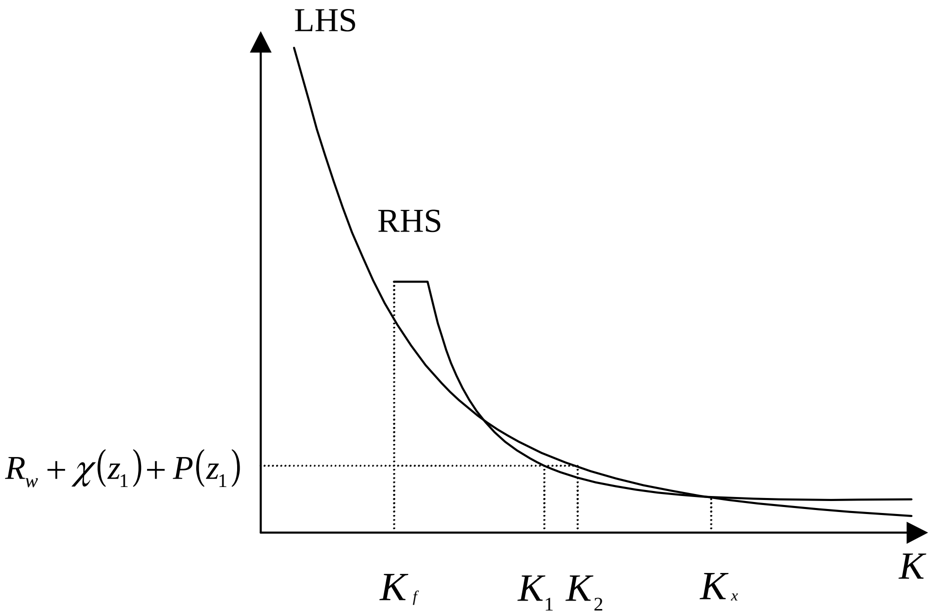

Figure 1

Consider the case that LHS and RHS do not intersect, i.e. LHS is strictly below RHS for all K. In this case the expected marginal product of capital does not cover the costs associated with investment in the small open economy, independent of the level of K. Hence, the unique equilibrium allocation of capital is characterized by $K = K_f$, implying $K^H = K_f$ and $K^F = 0$. Consider now the case that LHS and RHS do intersect. In that case the unique equilibrium allocation of capital is characterized by $K = K_x$, where K_x is defined as the highest K at which LHS and RHS intersect. If $K > K_x$ then the expected marginal product of capital does not cover the costs associated with investment. If $K < K_x$ then the market for information is not in equilibrium. The argument is best explained with an example: Take Figure 1. Suppose $z_1 = ... = z_N = 0$ and $K = K_f$, implying $K^H = K_f$ and $K^F = 0$. This could appear to be an equilibrium. The information suppliers' choice satisfies Proposition 1, investors located in the rest of the world do not invest since the expected marginal product of capital does not cover the costs associated with investment and workers hold their optimal portfolio. However, the market for information is not in equilibrium. It is a profitable deviation for any information supplier to produce a signal of quality $z_1 \in \Gamma\left(K_1^F\right)$, where $K_1^F = K_1 - L\psi\left(\frac{K_1}{L}\right)$ and K_1 is marginally below K_x, and to offer the signal at a price $P(z_1) = \frac{C(z_1)}{K_1^F} + c(z_1)$. Investors located in the rest of the world would invest until $K = K_2$ and the information supplier would make strictly positive profits, since $K_2 > K_1$. This argument applies whenever LHS and RHS intersect, since generically at the highest intersection RHS cuts LHS from below. Hence, the following condition is necessary and sufficient for an equilibrium allocation of capital

$$K^* = \begin{cases} K_f & \text{if LHS and RHS do not intersect,} \\ K_x & \text{otherwise.} \end{cases} \tag{24}$$

Equilibrium is now fully characterized: Equilibrium on the market for information is given by Proposition 1 and $K^{F*} = K^* - L\psi\left(\frac{K^*}{L}\right)$. The equilibrium allocation of capital is given by equation (24) and (21). The contract that a foreign owner offers a manager is given by equations (12) – (17) or equation (18). The labor market equilibrium is given by equation (20).

So far we have assumed that a foreign owner always prefers a contract that induces high effort to a contract that induces low effort. The assumption is easily relaxed. The optimal contract that induces high effort is associated with a net rate of return

$$E\left[R_j - x_j - P\left(z_j\right)|e_H\right] = E\left[R_j|e_H\right] - \left(\chi\left(0.5\right) + \tau\left(K^F\right)\right). \tag{25}$$

The optimal contract that induces low effort is associated with a net rate of return

$$E\left[R_j - x_j - P\left(z_j\right)|e_L\right] = E\left[R_j|e_L\right] - u^{-1}\left(\bar{U} + v\left(e_L\right)\right). \tag{26}$$

$E\left[R_j|e_L\right] < E\left[R_j|e_H\right]$ for given K, since low effort implies $\Theta_j = \Theta_L$ and $\frac{L_i}{K_i} > \frac{L_j}{K_j}$ when $\varepsilon = \varepsilon_H$. (See equation (19)). $E\left[R_j|e_L\right]$ as a function of K is depicted in Figure 2 by the downward sloping bold curve. The optimal contract that induces low effort implies costs associated with investment in the small open economy equal to $R_w + u^{-1}\left(\bar{U} + v\left(e_L\right)\right)$. These costs are depicted in Figure 2 by the horizontal bold curve. Define K_l as the aggregate capital stock at which the two curves intersect. The equilibrium allocation of capital is characterized by

$$K^* = \begin{cases} \max\left\{K_f, K_l\right\} & \text{if LHS and RHS do not intersect,} \\ \max\left\{K_x, K_l\right\} & \text{otherwise.} \end{cases} \tag{27}$$

Consider the case that LHS and RHS do not intersect. An investors located in the rest of the world does not invest with a contract that induces high effort. However, if $K_l > K_f$

then investors do invest with a contract that induces low effort until $K = K_l$. Consider next the case that LHS and RHS do intersect. If $K_x > K_l$ then $K = K_x$ otherwise the market for information is not in equilibrium. If $K_l > K_x$ then investors invest with a contract that induces low effort until $K = K_l$.

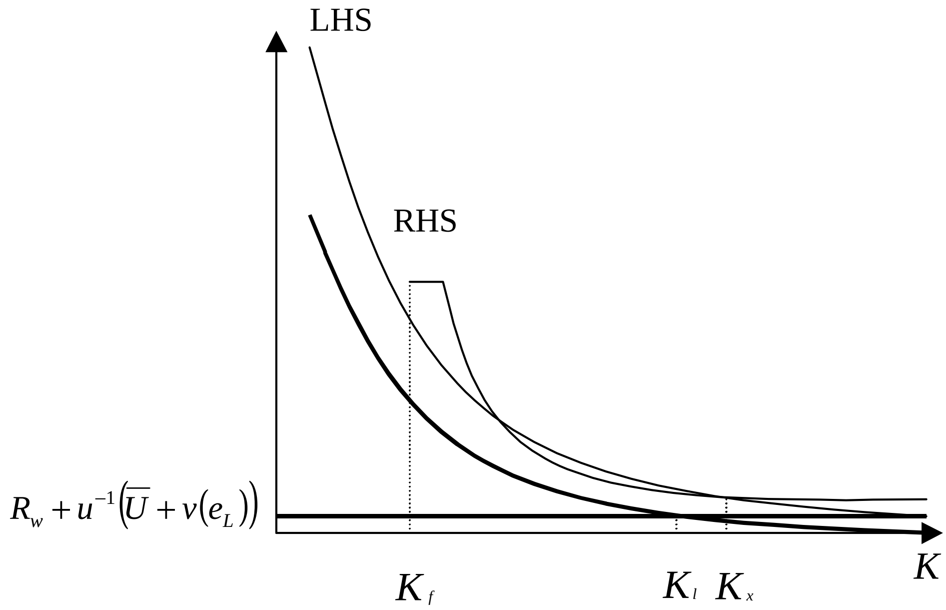

Figure 2

6 Discussion

Up to now we have analyzed the case that investors located in the rest of the world each allocate one unit of capital and cannot resell or share their signal. Now we analyze the other extreme. Investors located in the rest of the world can create an intermediary at no cost and thereby completely avoid duplication of the purchase of information. Assume that the cost of producing information is shared equally. Then the intermediary produces a signal of quality $z^* \in \Gamma\left(K^F\right)$, since $\Gamma\left(K^F\right)$ is the set of efficient signal qualities. Hence, results are identical. Possibly costs of transmitting the signal are saved.

Consider also the effect of a reduction in the cost of transmitting a signal, c. This comparative static exercise is motivated by the fact that the technology of transmitting information has changed a lot in the past and is likely to change further in the future.[10] In our model a reduction in the cost of transmitting a signal increases the *quality* of the produced signal. The reason is the following. First of all, $\hat{K}^F$ falls. Therefore, for some K^F for which no signal was produced before, a signal is produced after the reduction in c. Secondly, for the K^F for which a signal was produced before, $\Gamma\left(K^F\right)$ does not change but $P(z^*)$ falls. Hence, for all K^F greater than the new critical foreign owned capital stock, agency costs fall and RHS shifts down. If the country is very unproductive then $K^* = K_f$ and $z^* = 0$ before and after the reduction in the cost of transmitting a signal. If the country is fairly productive then $K^* = K_f$ and $z^* = 0$ before and $K^* = K_x$ and $z^* > 0$ after the reduction in the cost of transmitting a signal. If the country is very productive then $K^* = K_x$ and $z^* > 0$ before and after the reduction in the cost of transmitting a signal, but the equilibrium capital stock, K^*, increases and therefore the quality of the produced signal, z^*, increases.

Finally, consider welfare implications of the model. In every equilibrium investors located in the rest of the world earn an expected net rate of return equal to the world real interest rate and managers receive an expected utility equal to their outside option. Furthermore, workers' expected utility is strictly increasing in K. The proof is as follows. First of all, fix a worker's portfolio choice, a_s. Then

$$\begin{aligned}\frac{\partial E[\vartheta(\varkappa)]}{\partial k} &= \frac{\partial E[\vartheta(w + (1+R_i)a_s + (1+R_w)(a-a_s))]}{\partial k} \\ &= \frac{\partial E[\vartheta(f(k)\Theta - f'(k)\Theta k + (1+f'(k)\Theta)a_s + (1+R_w)(a-a_s))]}{\partial k} \\ &= E\left[\vartheta'(\varkappa) f''(k)\Theta(a_s - k)\right], \qquad (28)\end{aligned}$$

where $\varkappa$ is the worker's consumption, $k = \frac{K}{L}$, $f(k) = F(k,1)$ and $\Theta = \Theta_i = \Theta_j$. Since $a_s < k$ for all $k > k_f$, the expression on the right-hand side of equation (28) is strictly positive for all $K > K_f$. Secondly, allowing a worker to adjust his portfolio cannot make a worker worse off. Hence, a worker's expected utility is strictly increasing in K for all $K > K_f$. It follows that any equilibrium with a larger K^* strictly Pareto dominates any

[10] Reuters' technology of transmitting information has gone through many changes: from mail train and carrier pigeons (1849-1850) to telegraphic communication to long-wave radio to teleprinter to first computerized technologies to satellite distribution. It seems reasonable to assume that each of these changes has been associated with a reduction in the cost of transmitting information.

equilibrium with a smaller K^*. Note that a subsidy to foreign owned capital shifts RHS down. Hence, if $K^* \neq K_x$ (LHS and RHS do not intersect) and if for high effort the expected marginal product of capital is close to the costs associated with investment for some K with $K^F > \hat{K}^F$ (LHS and RHS almost intersect in the downward sloping segment of RHS) then taxing labor and subsidizing foreign owned capital is a welfare improving policy.

7 Conclusion

We have developed a model of a market for information, endogenized the information set of investors and derived the implications for the equilibrium allocation of capital. The model clearly shows that if producing information of higher quality is more costly, information once produced can be supplied infinitely often and there is free entry into the market for information then the quality of information provided by Reuters, Moody's or Economist Intelligence Unit is strictly increasing in the number of buyers. Hence, in equilibrium foreign investors investing in a country with a large foreign owned capital stock (e.g. Malaysia) purchase information of high quality and are well informed whereas foreign investors investing in a country with a small foreign owned capital stock (e.g. Morocco) purchase information of low quality and are less well informed. This result only requires monotonicity and differentiability of the value of information and the cost of producing information.

The dynamic implications of the model are analyzed in Wiederholt (2000). Finally, the model makes a number of testable predictions: Information is more likely to be produce about countries with a large foreign owned capital stock. The quality of produced information is strictly increasing in the foreign owned capital stock. The required return on capital is strictly decreasing in the foreign owned capital stock. Testing this predictions seems feasible, since estimates of foreign assets and liabilities have recently been created by Lane and Milesi-Ferretti (1999).

Appendix 1: Existence of an Optimal Contract

1. step: The constraint set is unbounded. However, one can add to the minimization problem the following constraint that will never be binding

$$(\underline{x},\underline{x},\underline{x},\underline{x}) \leq (x_{HH}, x_{HL}, x_{LL}, x_{LH}) \leq (\bar{x},\bar{x},\bar{x},\bar{x}), \tag{A1.1}$$

where $\underline{x}= u^{-1}\left(\bar{U}+v\left(e_H\right)-\frac{v(e_H)-v(e_L)}{q(0.5+z)}\right)$ and $\bar{x} = u^{-1}\left(\bar{U}+v\left(e_H\right)+\frac{v(e_H)-v(e_L)}{q(0.5+z)}\right)$. The proof that this constraint will never be binding is as follows. Participation constraint and incentive-compatibility constraint are given by

$$q\left(0.5+z\right)u\left(x_{HH}\right)+q\left(0.5-z\right)u\left(x_{HL}\right)+$$
$$\left(1-q\right)\left(0.5+z\right)u\left(x_{LL}\right)+\left(1-q\right)\left(0.5-z\right)u\left(x_{LH}\right) \geq \bar{U}+v\left(e_H\right) \tag{A1.2}$$
$$q\left(0.5+z\right)\left[u\left(x_{HH}\right)-u\left(x_{LH}\right)\right]+q\left(0.5-z\right)\left[u\left(x_{HL}\right)-u\left(x_{LL}\right)\right] \geq v\left(e_H\right)-v\left(e_L\right). \tag{A1.3}$$

One can restrict attention to contracts that satisfy the participation constraint with equality, because if equation $(A1.2)$ was satisfied with strict inequality then reducing x_{LL} would yield a new contract that is still an element of the constraint set and that is associated with a strictly smaller expected payment to the manager. Due to the strict concavity of $u(.)$ and $z \in [0, 0.5)$ one can also restrict attention to contracts that satisfy the incentive-compatibility constraint with equality. If equation $(A1.3)$ was satisfied with strict inequality then reducing $u\left(x_{HH}\right)-u\left(x_{LH}\right)$ or $u\left(x_{HL}\right)-u\left(x_{LL}\right)$ without changing $E\left[u\left(x\right)|e_H\right]$ ($\Delta u\left(x_{HH}\right)<0$, $\Delta u\left(x_{LH}\right)>0$ and $q\left(0.5+z\right)\Delta u\left(x_{HH}\right)+\left(1-q\right)\left(0.5-z\right)\Delta u\left(x_{LH}\right)=0$) would yield a new contract that is still an element of the constraint set and that is due to the strict concavity of $u(.)$ associated with a strictly smaller expected payment to the manager. The same line of reasoning shows that one can furthermore restrict attention to contracts satisfying $u\left(x_{HH}\right)=u\left(x_{HL}\right) \geq u\left(x_{LL}\right) \geq u\left(x_{LH}\right)$. Finally, since the participation constraint has to be satisfied with equality and $u\left(x_{HH}\right)=u\left(x_{HL}\right) \geq u\left(x_{LL}\right) \geq u\left(x_{LH}\right)$ we have $u\left(x_{HH}\right) \geq \bar{U}+v\left(e_H\right)$ and $u\left(x_{LH}\right) \leq \bar{U}+v\left(e_H\right)$. Since the incentive-compatibility constraint has to be satisfied with equality we have

$$u\left(x_{HH}\right) = u\left(x_{LH}\right)+\frac{v\left(e_H\right)-v\left(e_L\right)}{q\left(0.5+z\right)}-\frac{q\left(0.5-z\right)}{q\left(0.5+z\right)}\left[u\left(x_{HL}\right)-u\left(x_{LL}\right)\right] \tag{A1.4}$$
$$u\left(x_{LH}\right) = u\left(x_{HH}\right)-\frac{v\left(e_H\right)-v\left(e_L\right)}{q\left(0.5+z\right)}+\frac{q\left(0.5-z\right)}{q\left(0.5+z\right)}\left[u\left(x_{HL}\right)-u\left(x_{LL}\right)\right]. \tag{A1.5}$$

Hence,

$$u(x_{HH}) \leq \bar{U} + v(e_H) + \frac{v(e_H) - v(e_L)}{q(0.5+z)} \tag{A1.6}$$

$$u(x_{LH}) \geq \bar{U} + v(e_H) - \frac{v(e_H) - v(e_L)}{q(0.5+z)}. \tag{A1.7}$$

2. step: We have shown above that, without loss, one can restrict attention to contracts satisfying equation (10), (11) and $(A1.1)$. This new constraint set is clearly a bounded subset of R^4. Since $u(.)$ is continuous, it is also a closed subset of R^4. Hence the new constraint set is a compact set. The objective function is a continuous function on R^4. It follows from the Weierstrass Theorem that a solution to the minimization problem exists.

Appendix 2: Derivation of the Optimal Contract

1. step: Restate the minimization problem as a convex minimization problem. Define $(u_{HH}, u_{HL}, u_{LL}, u_{LH}) \equiv (u(x_{HH}), u(x_{HL}), u(x_{LL}), u(x_{LH}))$. Define $\psi(.)$ as the inverse function of $u(.)$ and denote the domain of ψ by D. Now restate the problem as a problem of choosing the manager's utility in different states of the world

$$\min_{(u_{HH}, u_{HL}, u_{LL}, u_{LH}) \in \mathsf{D}^4} E[\psi(u)|e_H] \qquad s.t. \tag{A2.1}$$

$$E[u - v(e)|e_H] \geq \bar{U} \tag{A2.2}$$

$$E[u - v(e)|e_H] \geq E[u - v(e)|e_L]. \tag{A2.3}$$

D^4 is an open and convex set. The objective function is a convex C^1 function mapping D^4 into R. The two constraints are concave C^1 functions mapping D^4 into R. In addition, Slater's condition is satisfied, i.e. there exists a vector $(u_{HH}, u_{HL}, u_{LL}, u_{LH}) \in \mathsf{D}^4$ that satisfies both constraints with strict inequality. The argument is simple. We know that a minimum exists and that a minimum satisfies both constraints. Increasing u_{HH} yields a new vector with the desired property. It follows from the Kuhn-Tucker Theorem under Convexity (see Sundaram (1996), p. 187) that the following first-order conditions are necessary and sufficient for a minimum

$$\psi'(u_{HH}) = \gamma + \mu\left(1 - \frac{\pi_{HH,e_L}}{\pi_{HH,e_H}}\right) \quad (A2.4)$$

$$\psi'(u_{HL}) = \gamma + \mu\left(1 - \frac{\pi_{HL,e_L}}{\pi_{HL,e_H}}\right) \quad (A2.5)$$

$$\psi'(u_{LL}) = \gamma + \mu\left(1 - \frac{\pi_{LL,e_L}}{\pi_{LL,e_H}}\right) \quad (A2.6)$$

$$\psi'(u_{LH}) = \gamma + \mu\left(1 - \frac{\pi_{LH,e_L}}{\pi_{LH,e_H}}\right) \quad (A2.7)$$

$$\gamma \geq 0, \quad \gamma\left(E\left[u - v(e)\,|e_H\right] - \bar{U}\right) = 0 \quad (A2.8)$$

$$\mu \geq 0, \quad \mu\left(E\left[u - v(e)\,|e_H\right] - E\left[u - v(e)\,|e_L\right]\right) = 0 \quad (A2.9)$$

plus the two constraints of course.

2. step: Equation $(A2.4)$ is equivalent to equation (12). Using $\psi'(u_{HH}) = \frac{1}{u'(x_{HH})}$, solving for x_{HH} and plugging in the probabilities yields equation (12). Due to the same arguments equations $(A2.5) - (A2.7)$ are equivalent to equations (13) – (15).

3. step: At a minimum $\gamma > 0$ and $\mu > 0$. First of all, suppose $\gamma = 0$. Then equation $(A2.6)$ would be violated, because $\psi'(u_{LL}) > 0$, $\mu \geq 0$ and $1 - \frac{\pi_{LL,e_L}}{\pi_{LL,e_H}} < 0$. Hence, $\gamma > 0$. Secondly, suppose $\mu = 0$. Then equations $(A2.4) - (A2.7)$ would imply that the optimal contract is a fixed payment. However a fixed payment violates the incentive-compatibility constraint. Hence, $\mu > 0$. Furthermore, it follows from $\gamma > 0$, $\mu > 0$ and the two complementary-slackness conditions that at a minimum the participation constraint and the incentive-compatibility constraint have to hold with equality.

Appendix 3: Proof of Lemma 1

$\mathsf{z}=\mathsf{0}$: The optimal contract at $z=0$ has the property $x_{HH}=x_{HL}$ and $x_{LL}=x_{LH}$. See equations $(12)-(15)$. Consider an increase in the quality of the signal to $z'>0$. It is easy to check that the formerly optimal contract is still an element of the constraint set and that it is still associated with the same expected payment to the manager. Furthermore, from equations $(12)-(15)$ we know that this contract is not the optimal contract any more, since at $z'>0$ the optimal contract has the property $x_{LL}>x_{LH}$. Hence, increasing the quality of the signal must make the principal strictly better off.

$\mathsf{z}\in(\mathsf{0},\mathsf{0.5})$: Denote the optimal contract at z by $(x^*_{HH},x^*_{HL},x^*_{LL},x^*_{LH})$ and the value function at z by $\chi(z)$. Consider an increase in the quality of the signal to z'. At $z'>z$ there exists a new contract $(x'_{HH},x'_{HL},x'_{LL},x'_{LH})$ that is an element of the constraint set and that is associated with an expected payment to the manager that is strictly smaller than $\chi(z)$. This contract is defined by $x'_{HH}=x'_{HL}=x^*_{HH}=x^*_{HL}$, $u(x'_{LL})=\frac{z'+z}{2z'}u(x^*_{LL})+\frac{z'-z}{2z'}u(x^*_{LH})$ and $u(x'_{LH})=\frac{z'-z}{2z'}u(x^*_{LL})+\frac{z'+z}{2z'}u(x^*_{LH})$. The proof is as follows. First of all, it is easy to check that

$$\begin{aligned}E\left[u\left(x'\right)|e_H\right] &= qu\left(x'_{HH}\right)+(1-q)\left[\left(0.5+z'\right)u\left(x'_{LL}\right)+\left(0.5-z'\right)u\left(x'_{LH}\right)\right]\\ &= qu\left(x^*_{HH}\right)+(1-q)\left[(0.5+z)u\left(x^*_{LL}\right)+(0.5-z)u\left(x^*_{LH}\right)\right]\\ &= \bar{U}+v\left(e_H\right) \qquad \text{(A3.1)}\end{aligned}$$

$$\begin{aligned}E\left[u\left(x'\right)|e_H\right]-E\left[u\left(x'\right)|e_L\right] &= qu\left(x'_{HH}\right)-q\left[\left(0.5-z'\right)u\left(x'_{LL}\right)+\left(0.5+z'\right)u\left(x'_{LH}\right)\right]\\ &= qu\left(x^*_{HH}\right)-q\left[(0.5-z)u\left(x^*_{LL}\right)+(0.5+z)u\left(x^*_{LH}\right)\right]\\ &= v\left(e_H\right)-v\left(e_L\right). \qquad \text{(A3.2)}\end{aligned}$$

Thus at $z'>z$ the new contract is an element of the constraint set. Secondly,

$$\begin{aligned}E\left[x'|e_H\right] &= qx'_{HH}+(1-q)\left[\left(0.5+z'\right)x'_{LL}+\left(0.5-z'\right)x'_{LH}\right]\\ &< qx^*_{HH}+(1-q)\left[(0.5+z)x^*_{LL}+(0.5-z)x^*_{LH}\right]\\ &= \chi(z). \qquad \text{(A3.3)}\end{aligned}$$

The reason for the strict inequality is that $x^*_{LL}>x'_{LL}>x'_{LH}>x^*_{LH}$, strict concavity of $u(.)$ and $(0.5+z')u(x'_{LL})+(0.5-z')u(x'_{LH}) = (0.5+z)u(x^*_{LL})+(0.5-z)u(x^*_{LH})$

implies that $(0.5+z')\,x'_{LL}+(0.5-z')\,x'_{LH}<(0.5+z)\,x^*_{LL}+(0.5-z)\,x^*_{LH}$. Thus at $z'>z$ the new contract is associated with an expected payment to the manager that is strictly smaller than $\chi(z)$. Hence, increasing the quality of the signal must make the principal strictly better off.

Appendix 4: Proof of Lemma 2

1. step: For all $z\in[0,0.5)$, the expected payment to the manager associated with the optimal contract is given by

$$\begin{aligned} E\left[x^*|e_H\right] &= q\,(0.5+z)\,\varphi\left(\frac{1}{\gamma+\mu}\right)+q\,(0.5-z)\,\varphi\left(\frac{1}{\gamma+\mu}\right)+(1-q)\,(0.5+z) \\ &\quad \varphi\left(\frac{1}{\gamma-\mu\frac{q(0.5-z)}{(1-q)(0.5+z)}}\right)+(1-q)\,(0.5-z)\,\varphi\left(\frac{1}{\gamma-\mu\frac{q(0.5+z)}{(1-q)(0.5-z)}}\right). \end{aligned} \tag{A4.1}$$

The function $\varphi(.)$ is a C^1 function. Furthermore equation (15) and $u'(.)>0$ implies $\gamma-\mu\frac{q(0.5+z)}{(1-q)(0.5-z)}>0$. Hence, $E\left[x^*|e_H\right]$ is a C^1 function of z for all $z\in(0,0.5)$ if the multipliers γ and μ are C^1 functions of z for all $z\in(0,0.5)$. The latter is proved below.

2. step: The Lagrange multipliers are found by plugging the optimal contract given by equations (12) – (15) into equation (16) and (17). This yields a system of two equations in the two unknowns γ and μ and in the parameter z

$$E\left[u\left(x^*\right)|e_H\right]-v\left(e_H\right)-\bar{U}=0 \tag{A4.2}$$

$$E\left[u\left(x^*\right)|e_H\right]-E\left[u\left(x^*\right)|e_L\right]-v\left(e_H\right)+v\left(e_L\right)=0. \tag{A4.3}$$

The left-hand side of equation $(A4.2)$ and the left-hand side of equation $(A4.3)$ are C^1 functions of the two unknowns γ and μ and the parameter z, for all $z\in(0,0.5)$. Furthermore the Jacobian matrix with respect to the two endogenous variables is

$$J=\begin{bmatrix} \frac{\partial E[u(x^*)|e_H]}{\partial\gamma} & \frac{\partial E[u(x^*)|e_H]}{\partial\mu} \\ \frac{\partial E[u(x^*)|e_H]}{\partial\gamma}-\frac{\partial E[u(x^*)|e_L]}{\partial\gamma} & \frac{\partial E[u(x^*)|e_H]}{\partial\mu}-\frac{\partial E[u(x^*)|e_L]}{\partial\mu} \end{bmatrix}. \tag{A4.4}$$

Straightforward but tedious calculations yield that $|J|=J_{11}J_{22}-J_{21}J_{12}>0$ for all $z\in(0,0.5)$ implying that the Jacobian matrix has full rank for all $z\in(0,0.5)$. It follows from the Implicit Function Theorem that the Lagrange multipliers γ and μ are C^1 functions of the quality of the signal z, for all $z\in(0,0.5)$.

Appendix 5: Proof of Proposition 1

Condition 1: 1. step: $\{(z_1, P(z_1)), ..., (z_N, P(z_N))\}$ is a Nash equilibrium of the information suppliers' entry game only if at most one information supplier produces a signal of quality $z \in (0, 0.5]$. Suppose two information suppliers produce a signal of quality $z \in (0, 0.5]$. Then there exists a profitable deviation. First of all, both information suppliers face strictly positive costs. Non-negative profits require that both information suppliers quote strictly positive prices and satisfy strictly positive demand. Since all foreign investors are identical, the latter implies that each foreign investor has to be indifferent between the two signals at the quoted prices. Secondly, average costs are strictly decreasing in the number of buyers. Therefore, quoting an infinitesimally lower price for one signal increases the demand for that signal and decreases the average costs of producing that signal. Hence, quoting an infinitesimally lower price is a profitable deviation for both information suppliers. 2. step: If $\Gamma\left(K^F\right)$ is non-empty and $0 \notin \Gamma\left(K^F\right)$ then $\{(z_1, P(z_1)), ..., (z_N, P(z_N))\}$ is a Nash equilibrium of the information suppliers' entry game only if at least one information supplier produces a signal of quality $z \in \Gamma\left(K^F\right)$. Suppose no information supplier produces a signal of quality $z \in \Gamma\left(K^F\right)$. Then there exists a profitable deviation. Producing a signal of quality $z \in \Gamma\left(K^F\right)$ and offering the signal at a price marginally above $\frac{C(z)}{K^F} + c(z)$ implies that all foreign investors demand the signal and that the associated profits are strictly positive. Hence, this is a profitable deviation for all information suppliers producing a signal of quality $z = 0$. 3. step: If $0 \in \Gamma\left(K^F\right)$ then $\{(z_1, P(z_1)), ..., (z_N, P(z_N))\}$ is a Nash equilibrium of the information suppliers' entry game only if all information suppliers produce a signal of quality $z \in \Gamma\left(K^F\right)$. Suppose one information supplier produces a signal of quality $z \notin \Gamma\left(K^F\right)$. Then there exists a profitable deviation. The information supplier producing the signal of quality $z \notin \Gamma\left(K^F\right)$ can only sell the signal at a price below $\frac{C(z)}{K^F} + c(z)$ and therefore associated profits are strictly negative. Hence, it is a profitable deviation for this information supplier to produce a signal of quality $z = 0$.

Condition 2: $\{(z_1, P(z_1)), ..., (z_N, P(z_N))\}$ is a Nash equilibrium of the information suppliers' entry game only if an information supplier producing a signal of quality $z^* > 0$ quotes a price such that profits are zero. Suppose the information supplier quotes a price such that profits are strictly positive or strictly negative. Then there exists a profitable deviation. In the first case it is a profitable deviation for an information supplier producing a signal of quality $z = 0$ to produce the signal of quality $z^* > 0$ and to quote a price marginally above $\frac{C(z)}{K^F} + c(z)$. In the second case it is a profitable deviation for the information supplier producing the signal of quality $z^* > 0$ to produce a signal of quality $z = 0$.

Appendix 6: Proof of Proposition 2

1. step: Define the value function $h : \mathsf{R}_+ \to \mathsf{R}$ by $h\left(K^F\right) = \min_{z \in [0,0.5]} \left(\chi(z) + \frac{C(z)}{K^F} + c(z)\right)$. The value function is non-increasing in K^F on R_+. This follows from the assumption that $C(z)$ is a fixed cost. Furthermore, $h\left(K^F\right) = \chi(0)$ for sufficiently small K^F. This follows from $\lim_{K^F \to 0} \frac{C(z)}{K^F} = \infty$ for any $z \in (0, 0.5]$. Finally, $h\left(K^F\right) < \chi(0)$ for sufficiently large K^F. This follows from $\lim_{K^F \to \infty} \frac{C(0.5)}{K^F} = 0$ and $c < \chi(0) - \chi(0.5)$. Hence, there exists a $\hat{K}^F > 0$ such that $h\left(K^F\right) = \chi(0)$ for all $K^F < \hat{K}^F$ whereas $h\left(K^F\right) < \chi(0)$ for all $K^F > \hat{K}^F$. Thus $0 \in \Gamma\left(K^F\right)$ for all $K^F < \hat{K}^F$ whereas $0 \notin \Gamma\left(K^F\right)$ for all $K^F > \hat{K}^F$.

2. step: $\Gamma\left(K^F\right)$ is single valued for all $K^F < \hat{K}^F$. For $K^F = 0$ this is obvious. For $K^F \in \left(0, \hat{K}^F\right)$ the proof is via contradiction. Suppose the contrary: $0 \in \Gamma\left(K_1^F\right)$ and $z^* \in \Gamma\left(K_1^F\right)$ with $z^* > 0$, for some $K_1^F \in \left(0, \hat{K}^F\right)$. Since K_1^F is an element of the open set $\left(0, \hat{K}^F\right)$ there exists an $r > 0$ such that the open ball with center K_1^F and radius r is an element of the set $\left(0, \hat{K}^F\right)$. Since $\frac{C(z^*)}{K^F}$ is strictly decreasing in K^F for all $z^* > 0$, we have $h\left(K^F\right) < \chi(0)$ for all $K^F > K_1^F$. Hence, we arrive at a contradiction.

Appendix 7: Proof of Proposition 3

1. step: Define $g : [0, 0.5] \times \mathsf{R}_{++} \to \mathsf{R}$ by $g\left(z, K^F\right) = -\left(\chi(z) + \frac{C(z)}{K^F} + c(z)\right)$. The function g has two important properties: First of all, g is a C^1 function on the interior of its domain. This follows from the result that $\chi(z)$ is a C^1 function on $(0, 0.5)$ and the assumption that $C(z)$ and $c(z)$ are C^1 functions on $(0, 0.5)$. Secondly, g has increasing marginal returns on the interior of its domain, i.e. $\frac{\partial g\left(z, K^F\right)}{\partial z} = -\left(\chi'(z) + \frac{C'(z)}{K^F} + c'(z)\right)$ is

strictly increasing in K^F. This follows from the assumption that $C'(z) > 0$ and that $C(z)$ is a fixed cost.

2. step: Let $z_1 \in \Gamma\left(K_1^F\right) = \arg\max_{z\in[0,0.5]} g\left(z, K_1^F\right)$ and $z_2 \in \Gamma\left(K_2^F\right) = \arg\max_{z\in[0,0.5]} g\left(z, K_2^F\right)$. g is a C^1 function and has increasing marginal returns on the interior of its domain. Suppose $z_1 \in (0, 0.5)$. It follows from the Strict Monotonicity Theorem 1 in Edlin and Shannon (1998) that $K_2^F > K_1^F$ implies $z_2 > z_1$.

Appendix 8: Proof of Proposition 4

A worker solves the following portfolio problem

$$\begin{aligned}\max_{a_s\in[0,a]} \quad E\left[\vartheta(x)\right] \quad s.t. \quad x &= w + (1+R_w)(a-a_s) + (1+R_i)\,a_s \\ &= f(k)\,\Theta - f'(k)\,\Theta k + (1+R_w)(a-a_s) + \left(1+f'(k)\,\Theta\right)a_s \\ &= f(k)\,\Theta + a + R_w(a-a_s) + f'(k)\,\Theta\,(a_s-k)\,, \qquad \text{(A8.1)}\end{aligned}$$

where $k = \frac{K}{L}$, $f(k) = F(k,1)$ and $\Theta = \Theta_i = \Theta_j$. An equivalent problem is

$$\max_{a_s\in[0,a]} \quad E\left[\vartheta\left(f(k)\,\Theta + a + R_w(a-a_s) + f'(k)\,\Theta\,(a_s-k)\right)\right]. \qquad \text{(A8.2)}$$

Denote the objective function $g(a_s,k)$ and the set of maximizers $\psi(k) = \arg\max_{a_s\in[0,a]} g(a_s,k)$.

A number of results follow. First of all, $\psi(k)$ is a continuous function on R_+. Consider first the interval $[0,k_1]$, where k_1 satisfies $f'(k_1)\,\Theta_L > R_w$. Such a number exists, since $\lim_{k\to 0} f'(k) = \infty$ and $\Theta_L > 0$. For all $k \in [0,k_1]$, we have $f'(k)\,\Theta > R_w$ in all states of the world and thus $\psi(k) = a$. Consider next the interval $[k_2,\infty)$, where k_2 satisfies $0 < k_2 < k_1$. The objective function $g : [0,a] \times [k_2,\infty) \to \mathsf{R}$ is continuous on its domain and strictly concave in a_s for each k. It follows from the Maximum Theorem under Convexity that $\psi(k)$ is a continuous function on the interval $[k_2,\infty)$. (See Sundaram (1996), p. 237.) Hence $\psi(k)$ is a continuous function on the whole interval $[0,\infty)$. Secondly, $\psi(k)$ has a fixed point on the interval $[0,a]$. On the interval $[0,a]$ we have $\psi : [0,a] \to [0,a]$ and ψ is a continuous function. It follows from Brouwer's Fixed Point Theorem that ψ has a fixed point $k_f = \psi(k_f)$ on $[0,a]$. Thirdly, $\psi(k)$ is non-increasing at $k = k_f$. If $k_f = a$ this is trivial. If $k_f \in (0, a)$ then we have an interior solution and therefore

$$\left. \frac{\partial g\left(a_s, k\right)}{\partial a_s} \right|_{\left(a_s, k\right) = \left(k_f, k_f\right)} = 0. \tag{A8.3}$$

It is easy to check that

$$\left. \frac{\partial^2 g\left(a_s, k\right)}{\partial a_s \partial k} \right|_{\left(a_s, k\right) = \left(k_f, k_f\right)} < 0. \tag{A8.4}$$

Furthermore $g\left(a_s, k\right)$ is strictly concave in a_s for each k. Thus an increase in k at $k = k_f$ leads to a strict decrease in the maximizer $\psi\left(k\right)$. Finally note that $k_f > 0$ since $\psi\left(0\right) = a$. Fourthly, the fixed point k_f is unique, since $\psi\left(k\right)$ is continuous on R_+ and non-increasing at $k = k_f$.

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