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Market discipline, competition for deposit, and banks risk taking in
emerging economies

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Keywords: banking competition, disclosure, deposit insurance, market discipline.

JEL classification: G21, G28, F39, L60

1 Introduction

The actual context of financial crisis reinforces the proposal of more sophisticated methods of risk controls in the banking sector (included in Basel II agreement). This subject appears doubly crucial for emerging economies. First, in their highly uncertain environment, information problems are more acute and the production of information is more problematic and may cause excessive risk taking in banking (Vives, 2006), whereas the low development of financial markets give a major role to banks in these economies. Second, their ambitious intents in compliance are quite remarkable ¹ (BIS 2006, FSI-BIS 2008). But according to a broad analysis (Powell 2002, Fisher 2002, Llewellyn 2003, Balin 2008), the banking systems in emerging economies may have difficulties to

adopt a sophisticated approach initially intended for advanced countries (non-members of Basel Committee). These authors highlight the structural weakness of the financial environment in emerging economies captured by the low quality of accountancy data, the lack of auditing agencies, problems in accounting and auditing procedures, lack of high-skilled employees to implement sophisticated measurement of risk.

Our paper intend to model a setup in which market discipline induced by international competition for deposits may incite to the adoption of a scrupulous strategy on risk management mitigating the excessive risk taking in banking of emerging economies. We analyze the above issue in a setup of competition between an emergent and a developed country to attract depositors.

This competition framework is motivated by the increasing degree of openness of such economies with respect to the OECD countries. Higher openness translates in higher possible mobility of capital. Therefore, banks in emerging and developing countries must compete with banks of developed countries to keep home their depositors². Among various determinants of capital flight, evidence of lack of confidence in the banking system appears for countries subjected by bank crisis such Russia or East Asian countries (Collier et al. 1999, Loungani and Mauro 2000, Perotti 2002). In the spirit of Vives (2002 and 2006) who has developed the notion of "external market discipline", our setup introduces a new channel through which depositors can exercise market discipline through the reallocation of saving from their country to a more protective system. By contrast with Vives (2006), we make the 'outside' pressure more direct by assuming a direct interaction in the same market of "outside" banks (those belonging to the developed country) and "inside" banks (those of the emerging country).

Market discipline³ induced by depositors' behavior is well empirically documented for emerging economies. These studies test the reaction of depositors in response to high risk-taking of banks by analyzing changes in deposit and deposit interest rates. In Latin America, empirical evidence of market discipline are found by Barajas and Steiner (2000) for Colombia, Calomiris and Powell (2002) for Argentina, Martinez-Peria and Schmukler (2001) for Argentine, Mexico, and Chile. More recently, Ugan et al. 2008 measure for Russia that depositors significantly increase their deposits with increase in capital and liquidity. Similar evidence is also found in Onder and Ozyildirim (2008) for Turkey.

Furthermore, market discipline exerted through the interest rate or by reallocation of deposits may be affected by legislations as for example deposit insurance or an extensive government guarantee. Demirgüç-Kunt and Huizinga (2004) examine this issue for a sample of 30 countries, including developed and developing countries, over the 1990–1997 period. They find that deposit insurance indeed weakens market discipline through deposit interest rates. According to Martinez-Peria and Schmukler (2001), deposit insurance do not decrease the market discipline effect. This allow to conclude to a low credibility of the deposit guarantee. On the other hand, Angkinand A., Wihlborg C. (2008) find a U-shaped relationship between explicit deposit insurance coverage and banks'

risk-taking. In their case such relationship is influenced by country specific institutional factors like the bank ownership type. In our paper, we consider that each country has a deposit insurance policy. We show how this policy interacts with market discipline and countries' competition.

One of the main contributions of this paper is to show how the risk taking behavior of the banks in the emergent country depends on the features of the banking system, captured by the degree of disclosure. We find that there is no univoque relationship between disclosure and risk taking. This relationship depends on the degree of financial openness of the emergent country, which affects the effectiveness of market discipline. Consequently, if the emergent country is not that opened, more disclosure does not bring less risk taking by banks, because depositors can exercise less market discipline. The contrary holds when the emergent country is quite open. In this last case, depositors exercise market discipline more effectively, so more disclosure induces a risk prudent attitude by banks.

Secondly, we find that the likeness of the risky choice is a turned U shaped curve function of the level of deposit insurance. This non monotonicity depends on the degree of market discipline.

The paper is organized as follows. The next section presents the model. Section 3 discusses the risk taking behavior of the banking system in the emergent country. Conclusions are provided in Section 4.

2 The model

Consider two countries h and f , where h is the emergent country and f the developed one. The banking system⁴ in the emergent country is not attractive to investors of the developed region. On the other hand, depositors of the developing country may decide to invest their savings in the developed region.

Banks Banks offer a given interest rate r_i ($i = h, f$) to depositors and lend the raised funds in compliance with a risk-sensitive prudential framework. Bank in h may choose between two strategies represented as a set $\{m, M\}$, where m stands for "high risk taking" and M for "safe risk management". For simplicity we assume that banks in the developed country always comply⁵. Banks in both countries are supposed to be risk indifferent and have limited liability. By choosing action m , the bank in h invests in a portfolio that yields r with probability p_m and zero otherwise. Opting for M delivers a return r with probability p_M , with $p_M > p_m$. For sake of simplification, we assume that action M eliminates⁶ credit risk while action m does not, namely $p_m = p$ and $p_M = 1$.

Pursuing strategy i ($= m, M$) entails a unit cost c_i , which results from assessing and monitoring risks and holding regulatory capital. Since it is more costly to implement safe risk management we consider that $c_M > c_m$. We shall simplify by setting $c_M = c > 0$ and $c_m = 0$. For reasons of consistency, it is assumed that $r > c$.

We consider that the adoption of safe risk management by the bank and its

impact on the probability of default is not perfectly visible to the depositors in h . The reason stems from the fact that investors are not endowed with sufficient financial and accounting expertise⁷. This lack of expertise can be fulfilled or aggravated by the institutions' quality that leads to more or less information. Let $1 - q_h$ denote the perceived probability of credit loss if strategy M is taken and the capital is invested at home. In the worst scenario, q_h would equal p and in the best one it would equal 1 ($p \leq q_h \leq 1$). Similarly, let $1 - q_f$ denote the perceived probability of credit loss if strategy M is taken and the capital is invested abroad, with $q_f > q_h$ ⁸. Without loss of generality assume $q_f = 1$ and denote $q_h = q$. From now on, q represents the degree of disclosure in the emergent country.

Finally, we consider a deposit insurance scheme specific to each country, namely a fraction β_i ($i = h, f$) of deposits, $0 < \beta_i < 1$ is returned back to depositors if a bank fails. Moreover, we assume that protection is not higher in the emergent economy than in the developed region i.e. $\beta_f \geq \beta_h$ ⁹. Again, without loss of generality assume $\beta_f = 1$ and denote $\beta_h = \beta$.

Depositors Population of h is spread with constant density S over a segment of unit length. The location of each investor of h may be interpreted as a distance in terms of preference to invest in the own banking place rather than abroad. Assume also that the cost of investing abroad is multiplied by a parameter k that represents the unit mobility cost. The higher this coefficient, the less the international mobility of investors will be. Risk indifferent investors should decide whether to invest in their own country or abroad. Such movements embody the market discipline. Depositors select the country that offers the highest expected return net of the mobility costs (if they invest in the developed region). The expected utility of depositor located at $x, x \in [0, 1]$, who invests in his own country h , is given by the expected utility over the states, bank failure or bank success and for the scenarios: (i) high risk adoption (m) and (ii) low risk adoption (M), namely:

$$U_h(x) = \begin{cases} p(1 + r_h) + (1 - p)\beta & \text{if } h \text{ chooses } m \\ q(1 + r_h) + (1 - q)\beta & \text{if } h \text{ chooses } M \end{cases}$$

If the same depositor invests in country f , his expected utility becomes:

$$U_f(x) = (1 + r_h) - k(1 - x) \quad (1b)$$

It follows that when the emergent country chooses strategy m , the marginal depositor's position is:

$$x_m = 1 - \frac{(r_f - p(1 + r_h) - \beta(1 - p) + 1)}{k}$$

while when the emergent country adopts strategy M , the marginal depositor's position obtains as:

$$x_M = 1 - \frac{(1 + r_f) - \beta(1 - q) - q(1 + r_h)}{k}.$$

2.1 High risk taking

Each banking system selects the interest rate that maximizes its own profit by taking as given the rival's rate.

$$\begin{aligned} \text{Max}_{r_h} \Pi_h^m &= px_m S(r - r_h) \\ \text{Max}_{r_f} \Pi_f^m &= (1 - x_m) S(r - r_f - c). \end{aligned}$$

Solving the system of first order conditions we find the equilibrium interest rates r_h^m and r_f^m ¹⁰

$$r_h^m = r - \frac{2k - (1 - p)(1 + r - \beta) + c}{3p} \quad (1)$$

$$r_f^m = r - c - \frac{k + (1 - p)(1 + r - \beta) - c}{3} \quad (2)$$

The equilibrium market shares of h is

$$x_h^{*m} = \frac{2k - (1 - p)(1 + r - \beta) + c}{3k}, \quad (3)$$

Consequently, the market share for f is $x_f^m = 1 - x_h^m$. It is possible to check that $x_h^m \in (0, 1)$ if and only if

$$k > \frac{1}{2}(1 - p)(1 + r - \beta) - c \quad (4)$$

and $1 + r - \beta > \frac{4c}{3(1-p)}$.

The equilibrium profits of h and f write as

$$\begin{aligned} \Pi_h^{*m} &= (x_h^m)^2 kS \\ \Pi_f^{*m} &= (1 - x_h^m)^2 kS \end{aligned}$$

Notice that $\frac{\partial^* \Pi_h^m}{\partial k} > 0$ if $k > \frac{(1-p)(1+r-\beta)-c}{2}$. Thus, the lower is the financial integration between countries (higher k), the higher is the profitability of strategy m . Financial integration has a twofold effect, it decreases the market share x_h^{*m} ($\frac{\partial^* x_h^m}{\partial k} = \frac{(1+r-\beta)(1-p)-c}{3k^2} > 0$ for $1 + r - \beta > \frac{4c}{3(1-p)}$), and it increases the interest left to the bank, $r - r_h^m$ ($\frac{\partial^* r_h^m}{\partial k} < 0$). Clearly, financial integration, reduces the profitability of the high risk management strategy.

2.2 Safe risk management

Each banking system selects the interest rate that maximizes its own profit by taking as given the rival's rate.

$$\begin{aligned} \text{Max}_{r_h} \Pi_h^M &= x_M S(r - r_h - c) \\ \text{Max}_{r_f} \Pi_f^M &= S(1 - x_M)(r - r_f - c) \end{aligned}$$

After solving the system of best replies, we get the equilibrium the following interest rates

$$r_h^{*M} = r - c - \frac{2k - (1 - q)(1 + r - c - \beta)}{3q} \quad (5)$$

$$r_f^{*M} = r - c - \frac{k + (1 - q)(1 + r - c - \beta)}{3} \quad (6)$$

Notice that $\frac{\partial r_h^M}{\partial q} = \frac{2k - (1 - \beta + r) + c}{3q^2}$ can be positive or negative according as $k \leq \frac{1 + r - \beta - c}{2}$. While $\frac{\partial r_f^M}{\partial q}$ is always positive. Thus, the difference $r_h^M - r_f^M$ can increase or decrease as q increases, depending on the degree of financial openness.

The equilibrium market share of h becomes

$$x_h^{*M} = \frac{2k - (1 - q)(1 + r - \beta - c)}{3k}$$

which belongs to the interval $(0, 1)$ if and only if $k > \bar{k} = \frac{(1 - q)(1 + r - c - \beta)}{2}$. Thus, it can be proved that if

$$1 + r - \beta \in \left(\frac{4c}{3(1 - p)}; \frac{(1 + q)c}{q - p} \right) \quad (7)$$

the feasibility set of k reduces to¹¹:

$$k > \bar{k} \quad (8)$$

The equilibrium profit of countries write as

$$\begin{aligned} \Pi_h^{*M} &= (x_h^M)^2 \frac{kS}{q} \\ \Pi_f^{*M} &= (1 - x_h^M)^2 kS \end{aligned}$$

It can be checked that $\frac{\partial \Pi_h^M}{\partial q} > 0$ if $q > \left| \frac{1 + r - \beta - c - 2k}{1 + r - \beta - c} \right|$ ¹²; otherwise $\frac{\partial \Pi_h^M}{\partial q} < 0$. Hence, if initial disclosure is quite high in the developing country, more disclosure brings higher profits and makes the strategy M more attractive. This property is due to the multiple effects of disclosure. An increase of q : (i) increases market share for h ; (ii) it decreases r_h^M if financial integration is high enough ($k < \frac{1 + r - \beta - c}{2}$). When countries are financially integrated, attractiveness for deposits is built on the transparency of the probability of success, rather than on high interest rates. (iii) It increases r_h through the strategical increase of r_f (recall interest rates are strategic complements). If the initial level of q is quite high, the positive effects (i) and (ii) exceed the negative one in (iii). On the other hand, if q is not high enough, the third negative effect on interest rate dominates the positive effects of q . Thus, in this case the overall effect on profits is negative. Finally, for the same reasons as in the case of strategy m , the profit function Π_h^{*M} depends positively on k : $\frac{\partial \Pi_h^M}{\partial k} > 0$ since $k > \frac{(1 - q)(1 + r - \beta - c)}{2}$.

3 Analysis of risk taking

In this section, we study the interest of the emergent country to comply to a safe risk management strategy. This strategy is selected if $\Pi_h^m < \Pi_h^M$. We saw in the above sections that the profitability of strategy m depends negatively on the degree of financial integration because integration fosters market discipline. On the other hand, the degree of financial integration also affects negatively the profitability of strategy M . Thus, the effect of the size of k on the choice of the risk strategy is ambiguous. Furthermore, profit Π_h^M is not monotonic with respect to level of disclosure q . Therefore, the effect of disclosure (depending on size of q) and the effectiveness of market discipline (depends on size of k) can reinforce or offset each other, defining ultimately the profitability of strategy M as compared to strategy m .

By direct comparison Π_h^m and Π_h^M , it obtains

Proposition 1 *If the degree of financial openness of the emerging country (h) is not too high ($k > \tilde{k}$), there exists a cost threshold ($c^* > 0$) under which the banking system of h adopts safe risk management.*

Proof. The threshold-value $c^* = \frac{2k-(1-q)(1+r-\beta)-\sqrt{q}(2k-(1-p)(1+r-\beta))}{q+\sqrt{q}-1}$ derives from the equality $\Pi_h^m(c) = \Pi_h^M(c)$. It follows that $c^* > 0$ if $k > \tilde{k}$, where $\tilde{k} = (1+r-\beta) \frac{(1-q)-\sqrt{q}(1-p)}{2(1-\sqrt{q})}$ ¹³. Consequently, the strategy $s = M$ is chosen if the cost of implementing safe risk management satisfies $c \leq c^*$, whereas the banking system opts for risk taking ($s = m$) if $c > c^*$. ■

The above proposition identifies the range of financial integration that makes probable the compliance to the safe strategy, regardless of the degree of disclosure. In this range of parameters competition between banks is reduced to the extent of making irrelevant the degree of disclosure. To better examine the mechanisms defined in proposition 1, we shall analyse the effect of mobility cost on market share x_h and on the interest rate r_h , when either of the two strategies is selected.

When mobility cost is high enough, the threat of depositors to reallocate their deposits abroad is low - *low effectiveness of market discipline* -, ceteris paribus. The lack of such threat makes the market of the emergent country more "captive" for the local bank. Consequently, choosing strategy m is quite probable. Nevertheless, opting for m is not a dominant strategy, because of the different "volatility" of r_h^m and r_h^M with respect to k . More precisely, the size of variation of r_h^m with respect to k is higher than the variation of r_h^M , i.e. $\left| \frac{\partial r_h^m}{\partial k} \right| = \left| -\frac{2}{3p} \right| > \left| \frac{2}{3q} \right| = \frac{\partial r_h^M}{\partial k}$. Therefore, it is likely that a range of costs c exists, corresponding to which $\Pi_h^m < \Pi_h^M$.

Notice that $c^* > 0$ is always true when disclosure is high enough, namely $q \geq \tilde{q}(p)$ ¹⁴. So we may state the following proposition.

Proposition 2 *If disclosure is high enough ($q > \tilde{q}(p)$), there always exists a cost threshold ($c^* > 0$) under which the banking system of the emergent country adopts safe risk management notwithstanding its degree of financial openness.*

Proof. We know that $c^* > 0$ if $k > (1 + r - \beta) \frac{(1-q) - \sqrt{q(1-p)}}{2(1-\sqrt{q})}$. But for $q \geq \tilde{q}(p)$, we have $(1 + r - \beta) \frac{(1-q) - \sqrt{q(1-p)}}{2(1-\sqrt{q})} \leq 0$. So, if $q \geq \tilde{q}(p)$, for $\forall k \in R^+$ (therefore, also for the admissible set $k > \bar{k}$), we have $c^* > 0$. ■

Proposition 2 identifies the second reason why safe risk management can be an equilibrium strategy. If residents of h can appreciate the risk safe strategy of the local bank in h because $q > \tilde{q}(p)$, no matter how easily they can move towards f , there always exists a range of c , for which choosing safe risk strategy is a winning strategy for the bank in h . Proposition 2 provides such range of c . We may think of disclosure as the variable that captures the quality of information circulation and of institutions in the emerging country. In this perspective, proposition 2 is in line with Vives (2006) because it shows how important is the role of the institutions and environment on the risk attitude of banks.

From the previous propositions it results that $c^* \leq 0$ when $q < \tilde{q}(p)$ and $\bar{k} < k \leq \tilde{k}$. So, we may write the following corollary.

Corollary 3 *Safe risk management is never selected if disclosure is too low ($q < \tilde{q}(p)$) and financial openness is too large ($\bar{k} < k < \tilde{k}$).*

In these sets of parameters, the mobility of depositors is the highest, and contemporarily the disclosure of information concerning the probability of success of M is the lowest in the admissible set. Therefore, in this constellation of parameters, the benefits for the bank of a safe risk management (lower interest rates and higher market share) do not cover the cost c . This is the worse scenario for the capital in country h , because a large number of depositors will locate their savings in country f .

After establishing the likeliness of compliance to the safe strategy, we can further investigate the interaction of information disclosure and the effectiveness of market discipline by analysing the threshold cost c^* . We find that $\frac{\partial c^*}{\partial q} > 0$ if $k < k^*$ while $\frac{\partial c^*}{\partial q} < 0$ if $k > k^*$ where $k^* = \frac{p(1+q)(1+r-\beta)}{2(2\sqrt{q}-q)}$ ¹⁵. It follows

Proposition 4 *The higher the disclosure in the emergent country, the higher the likeliness of a safe risk taking attitude of the corresponding banking system if*

$$\bar{k} < k < k^*.$$

On the contrary, the higher disclosure, the lower the likeliness of safe risk taking attitude if

$$k > k^*.$$

The intuition behind proposition 4 can be explained as follows. Disclosure of more information or transparency, affects competition between banks as well as the attractiveness for depositors of the emergent country. These two forces can be isolated taking the total derivative with respect to q and c of profits comparison $\Pi_h^M - \Pi_h^m$ for $c = c^*$:

$$\frac{dc^*}{dq} = \frac{-\frac{\partial \Pi^M}{\partial q}}{\frac{\partial \Pi^M - \partial \Pi^m}{\partial c}}$$

The term $\frac{\partial \Pi^M - \partial \Pi^m}{\partial c}$ isolates the competition effect, while $\frac{\partial \Pi^M}{\partial q}$ represents the attractiveness effect. Proposition 3 shows how these magnitudes and the final effect depends on the degree of openness. When depositors have low cost to send their savings abroad due to countries' openness, disclosing more information at home is convenient for the bank to the extent of keeping home the major quantity of savings (attractiveness offsets competition effect). Hence, due to openness depositors exercise market discipline more easily, inducing the emergent country to choose the safe risk management. By contrast, when the risk of capital flight is low, $k > k^*$, depositors exercise little market discipline. Therefore, attractiveness is not very much affected, but countries do become more alike as q increases (countries are more alike to the extent of similarity of probability of success of their banking system, which leads to similarity of banking contracts that they should supply to depositors), thus for this range of openness, competition effect offsets attractiveness hence $\frac{dc^*}{dq} > 0$.

Moreover, it is easy to see that $\frac{\partial^2 c^*}{\partial q \partial \beta} < 0$. The sign of this cross derivative says that in presence of increasing deposit insurance, disclosing more information does not reduce the likeness of risk taking behavior of the bank in the developing country.

3.1 Deposit insurance

Finally, we analyze the nature of the threshold c^* in presence of deposit insurance. For this purpose, we can calculate $\frac{\partial c^*}{\partial \beta}$, whose signs leads to

Proposition 5 *The higher β , the more likely it is that the banking system in the emergent country chooses to be risk safe if $q < \tilde{q}(p)$. On the contrary, the higher β , the less likely it is that the emergent country chooses to be risk safe if $q > \tilde{q}(p)$.*

When the level of disclosure is low, for given mobility cost, depositors are induced to quit h . The answer of the bank is to select the more safe strategy even for increasing levels of deposit insurance.

The second part of this proposition recalls the "moral hazard" behaviour of banks induced by deposit insurance schemes. Existing literature claims that the higher the level of deposit insurance, the higher is the risk taken by banks. In this model of countries' competition, the risky behavior of emergent country bank is due to competition for depositors rather than to moral hazard. Developing country may not comply to M in order to escape interest competition with the bank in the developed one. Depositors are compensated, for such higher risk, with higher deposit insurance. This property takes place for high levels of disclosure. This may appear countrintuitive, but in this setup high disclosure translates not only in high market discipline, but it also imply a fierce interest competition.

4 Conclusion

In this paper, we analyze the risk taking behavior of banks in emerging economies, in a context of international bank competition. In the spirit of Vives (2002 and 2006) who has developed the notion of "external market discipline", our paper introduces a new channel through which depositors can exercise market discipline to control risk taking. They can reallocate their savings away from their home country to a more protective system of a developed economy. In such a framework, we show that there is no univoque relationship between the degree of disclosure and risk taking. This relationship depends on the degree of financial openness of the emergent country, which ultimately defines how effective is the market discipline. Furthermore, we analyze the risk taking choice of banks in emergent economies in presence of deposit insurance. With this respect, we find a turned U-shaped relationship between the likeness of risk taking behavior of banks and the size of deposit insurance.

Notes

¹The 2008 FSI survey (FSI-BIS 2008, p. 2) indicates that 92 non members of the Basel Committee on Banking Supervision have implemented or are currently planning to implement Basel II. And 61 % of them intend to offer the Advanced Internal Ratings Based Approach (Advanced IRB).

²The increasing financial openness of emerging countries and its consequences are well measured by Prasad et al (2003) and in particular the evidence that the capital, except FDI, has tended to flow from poor to rich countries over the 2000s. (Prasad et al. 2006)

³Rochet (2004) defines direct market discipline as the behaviour of stakeholders that affects the strategy of managers and works as a substitute to prudential supervision. By contrast, indirect market discipline, which provides new objective information, works as a complement to prudential supervision.

⁴In order to simplify we suppose that the banking system of each jurisdiction contains one bank. This assumption allows to concentrate on inter-jurisdictional bank competition.

⁵This is a reasonable assumption, because it is safe to believe that the likeness of compliance is always higher in the developed countries rather than in developing ones.

⁶What is not equivalent with perfect risk diversification since risk mitigating costs are incurred.

⁷See Powell 2002 or Fisher 2002.

⁸This assumption is justified by the fact that banking sector of developed countries is characterized by less asymmetry of information and better insitutions' quality as compared with the enviroment where banks operate in developing countries.

⁹This assumption is in line with Hyytinen and Takalo (2002).

¹⁰The offered interest rates $r_i^m (i = h, f)$ will be positively signed for r sufficiently large.

¹¹The condition on k to assure positivity of interest rates and market shares in both outcomes is $\bar{k} = \text{Max} \left\{ (i) \frac{(1-q)(1+r-\beta-c)}{2}; (ii) \frac{(1-p)(1+r+\beta)}{2} - c; (iii) c - (1-p)(1+r-\beta) \right\}$.

As we saw, (ii)>(iii) if $c \frac{4}{3(1-p)} < 1+r-\beta$. Moreover, (i)>(ii) if $1+r-\beta < \frac{1+q}{q-p}c$. Thus, since $\frac{4}{3(1-p)}c < \frac{1+q}{q-p}c$, we obtain (i)>(ii)>(iii) if $c \frac{4}{3(1-p)} < 1+r-\beta < \frac{1+q}{q-p}c$.

¹²We calculate $\frac{\partial \Pi_h^M}{\partial q} > 0$ if $q > \frac{1+r-\beta-c-2k}{1+r-\beta-c}$ and $k < \frac{1+r-\beta-c}{2}$, or if $q > \frac{1+r-\beta-c-2k}{-(1+r-\beta-c)}$ and $k > \frac{1+r-\beta-c}{2}$. This is equivalently to: $\frac{\partial \Pi_h^M}{\partial q} > 0$ if $q > \left| \frac{1+r-\beta-c-2k}{1+r-\beta-c} \right|$ regardless of the value of k .

¹³Notice that if the inequality $1 + r - \beta > \frac{(1-q)(1-\sqrt{q})c}{(q-p)\sqrt{q}}$ holds, we have $\tilde{k} < \bar{k}$. In this case, the threshold c^* is always positive in the whole feasible set of mobility cost $k > \bar{k}$. Moreover, since the net returns $1 + r - \beta$ should satisfy (7), it can be easily checked by solving $\frac{(1-q)(1-\sqrt{q})c}{(q-p)\sqrt{q}} < \frac{4}{3(1-p)}c$ that if $q > 0.35$, we always have $\tilde{k} < \bar{k}$. On the other hand, if $q < 0.35$, we obtain $\frac{4}{3(1-p)}c < \frac{(1-q)(1-\sqrt{q})c}{(q-p)\sqrt{q}} < \frac{1+q}{q-p}c$. Thus, in this case, $c^* > 0$ if $k > \tilde{k}$.

¹⁴With $\tilde{q}(p) = \frac{1}{2} \left(p^2 + 3 - 2p - (1-p) \sqrt{p^2 + 5 - 2p} \right)$.

¹⁵Note that $k^* > \bar{k}$ for $p > \bar{p}(q)$, where $\bar{p}(q) = \frac{-q+q^2+2\sqrt{q}-2q^{\frac{3}{2}}}{7q-3q^2-6\sqrt{q}+6q^{\frac{3}{2}}+4}$.

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