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Exchange rate uncertainty and international technology transfer

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Abstract

We propose an incomplete contract model of licensing of a cost-reducing technology. We incorporate exchange rate uncertainty and analyze its impact on the parties' investment and licensing decisions. We show that exchange rate uncertainty introduces a distortion in the parties' specific investment decisions and could even prevent the transfer from taking place.

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1 Introduction

Access to superior technology increases firm efficiency and is a source of growth in total factor productivity, see Mendi (2007), which ultimately has a positive effect on growth. Hence, analyzing factors that influence access to foreign technology is relevant for the understanding of the determinants of a country's level of development.

This note studies how exchange rate uncertainty may become an obstacle to the acquisition of foreign process innovation. We propose a licensing model where the effective implementation of the new technology requires the undertaking of non-contractible investments by both the licensor and the licensee. In our model, exchange rate variations occur in the interim between the licensor and the licensee's specific investment decisions, and may reduce the licensor's incentives to invest. Anticipating this, the licensee's incentives to invest are likewise reduced. If this problem is serious enough we will show that for some parameter values there may be no fixed fee and/or royalty rate that both parties find acceptable to transfer the technology.

We focus on the transfer of a cost-reducing process technology, and we are not analyzing the entry mode decision (the choice between exporting, direct investment, and licensing) of the technology owner. Thus, we are implicitly assuming that the alternatives of exporting or direct investment are costlier than licensing. Under different assumptions, for instance the licensor producing a substitute product and being able to set up a subsidiary in the destination country, exchange rate uncertainty is likely to have a more limited effect on the transfer of technology.

Our model resembles that in Choi (2001), except that we consider an international transaction subject to exchange rate risk. We find increasing exchange rate uncertainty to decrease the likelihood of technology transfer, even assuming the parties to be risk-neutral, in contrast to Bousquet et al. (1998).

A number of papers have studied the impact of exchange rate fluctuations on investment and growth. For instance, Cottani et al. (1990) find a strong negative correlation between real exchange rate instability and per capita income growth, using a sample of developing countries. Darby et al. (1999) propose a theoretical model based on Dixit and Pindyck (1994) to find that increasing exchange rate volatility negatively affects investment. Using a panel of 14 sub-Saharan countries, Bleaney and Greenaway (2001) finds investment to be negatively affected by exchange rate instability. Servén (2003) also finds a negative effect of real exchange rate uncertainty on private investment, using a sample of developing countries. However, to the best of our knowledge, no contribution has analyzed the effect of exchange rate uncertainty on the transfer of technology at the firm level.

Our note stresses the importance of exchange rate stability to foster technological development, especially for countries that are very dependent on foreign technology. The existence of spillover effects at the local level amplify the potential positive effect of reducing exchange rate volatility on technological development, and ultimately, on total factor productivity and growth.

The structure of this note is as follows. We present the model in Section 2. Section 3 includes some numerical examples. Finally, Section 4 discusses the implications of the model and introduces some concluding comments.

2 The model

Consider a domestic monopolist in the production of a given product that faces a linear demand $p = 1 - q$, and uses technology that allows production to be carried out at constant marginal cost $c > 0$. A foreign patentee owns a cost-reducing process technology, which could allow a licensee to produce at a cost $c(e, i) = c_F(1 - e \cdot i)$, where $e, i \in [0, 1]$ are the licensor and licensee's normalized investment levels. The licensee's marginal cost is such that $c(0, i) = c(e, 0) = c_F \geq c$, $c(1, 1) = 0$, and $\frac{\partial c}{\partial e} \leq 0$, $\frac{\partial c}{\partial i} \leq 0$. Hence, the licensee's production cost is zero if and only if both the licensor and licensee choose the maximum investment levels. We assume irreversibility in the technology adoption decision, in the sense that if the licensee accepts the licensor's offer, it can not switch back to the existing technology. We may interpret i as investment in absorptive capacity, whereas e represents transfer of know-how. Let $\alpha(e) = \alpha \cdot e$ and $\beta(i) = \beta \cdot i$ be the licensor and licensee's investment costs. Linearity of these cost functions will give rise to corner solutions that will greatly simplify the analysis.

Our model focuses on arm's-length transfers of the technology from the licensor to the licensee. Consider contracts defined by F and r, where F is a fixed payment, independent of output produced, and r is a per unit royalty rate, which determine variable payments. Our analysis could be extended by considering the case of variable payments denominated in the foreign currency, as well as ad valorem royalty rates. All these payment schedules are widely used in actual contracts, see for instance Mendi (2005), or Vishwasrao (2007).

The exchange rate ρ is denominated in currency units of the licensor's country per unit of the currency of the licensee's country, and follows an ex-ante known distribution $U\left[\underline{\rho}, \overline{\rho}\right]$. We assume that the exchange rate is subject to variation in the interim between the licensee's choice of i and the licensor's choice of e. This assumption on timing is crucial in our results. If both parties could commit to choosing their investment levels before the exchange rate is observed, uncertainty would not have any effect, since both parties would make their decisions based on expected exchange rates. However, in our model an increase in variance increases the probability of the licensor not undertaking the required investment, since it makes its decision conditional on the realization of ρ.

We rule out the possibility of the licensee borrowing in the first period an amount equal to all future payments, converting them into foreign currency at parity, and making future payments as scheduled. Notice that this would eliminate the effect of exchange rate uncertainty. We assume this is not feasible either because of lack of credit market development in the licensee's country, or because of a long enough time span between the signing of the contract and the licensor's choice. We also rule out any other type of hedging against exchange rate risk. Of course, relaxing these constraints would increase the likelihood of an efficient transfer of technology.

The timing of the game is as follows:

1. The licensor makes the licensee a TIOLI licensing contract offer F, r, where F is a fixed payment, and r is the per unit royalty payment.

2. The licensee accepts or rejects the contract offer. If accept, the licensee chooses its investment in absorptive capacity i.

3. The exchange rate ρ is determined.

4. The licensor chooses its investment level e. The licensee's production costs $c(e,i)$ are thus determined.

5. Production takes place, and payments are realized as specified in the contract.

Notice that the licensor makes its choice of specific investment $e \in [0,1]$ after observing the realization of the exchange rate ρ. Hence, the licensor chooses a zero level of investment if the realization of the exchange rate is below some threshold level. We want to show that an increase in the variance of ρ may prevent the transfer from taking place, even though the expected exchange rate does not vary.

As it is usual in this type of games, we analyze the game backwards. This way, in stage 4, and given r, ρ, and i, the licensor's problem reads

$$\max_{0\leq e\leq 1} \rho \cdot \left[F + r \cdot \frac{1 - c_F(1-ei) - r}{2}\right] - \alpha \cdot e$$

The solution to the licensor's problem defines an optimal investment function $e^*(i,r)$. Notice that, given the functional form of the licensee's cost function, the licensor's revenues are linear in e, and so are its costs. Hence, the solution will be either $e^* = 0$ or $e^* = 1$. Specifically,

$$e^*(\rho\,|i,r) = \begin{cases} 0 \text{ if } \rho < \frac{2\alpha}{irc_F} \\ 1 \text{ if } \rho \geq \frac{2b\alpha}{irc_F} \end{cases}$$

Therefore, the licensee will choose $e^* = 1$ only if $\rho \geq \widetilde{\rho}(i) = \frac{2\alpha}{irc_F}$. Notice that if $\widetilde{\rho}(i) \leq \underline{\rho}$, then the licensor chooses $e^* = 1$ for any realization of the exchange rate. In contrast, if $\widetilde{\rho}(i) \geq \overline{\rho}$ the licensor always chooses $e^* = 0$. Finally, if $\widetilde{\rho}(i) \in \left(\underline{\rho}, \overline{\rho}\right)$ then $e^* = 1$ only for $\rho \in (\widetilde{\rho}(i), \overline{\rho}]$.

In the previous stage, and anticipating the licensor's optimal investment rule, the licensee's problem reads

$$\max_{0\leq i\leq 1} \frac{(1-c_F-r)^2}{4} \cdot \frac{\widetilde{\rho}(i) - \underline{\rho}}{\overline{\rho} - \underline{\rho}} + \frac{(1-c_F(1-i)-r)^2}{4} \cdot \frac{\overline{\rho} - \widetilde{\rho}(i)}{\overline{\rho} - \underline{\rho}} - F - \beta \cdot i$$

The licensee's profits and marginal profits increase with i. Hence, given the linearity of the investment cost function, the licensee will choose $i^* = 1$ as long as $[c_F \cdot (2(1-r) - c_F)] \cdot (\overline{\rho} - \widetilde{\rho}(1)) \geq 4\beta\left(\overline{\rho} - \underline{\rho}\right)$ and $i^* = 0$ otherwise. This defines an expression that is quadratic in r and thus an interval of values of the royalty rate such that the licensee chooses $i^* = 1$.

At the initial stage, the licensor chooses the royalty rate to maximize its own expected profits, subject to the licensee's expected profits exceeding those if using the existing technology, that is, the licensee's cost being c. The royalty rate r influences the licensee's choice of i and hence the range of realizations of the exchange rate such that $e^* = i^* = 0$ and those for which $e^* = i^* = 1$. Call this critical value $\widetilde{\widetilde{\rho}}(r)$. Then, the licensor's problem reads

$$\begin{aligned} &\max_{F,r\geq 0} F + \rho \cdot r \cdot \tfrac{a-c_F-r}{2} \cdot \tfrac{\widetilde{\widetilde{\rho}}(r)-\underline{\rho}}{\overline{\rho}-\underline{\rho}} + \rho \cdot r \cdot \tfrac{a-r}{2} \cdot \tfrac{\overline{\rho}-\widetilde{\widetilde{\rho}}(r)}{\overline{\rho}-\underline{\rho}} - \alpha \cdot e(r) \\ &\text{s.t. } \tfrac{(1-c_F-r)^2}{4} \cdot \tfrac{\widetilde{\widetilde{\rho}}(r)-\underline{\rho}}{\overline{\rho}-\underline{\rho}} + \tfrac{(1-r)^2}{4} \cdot \tfrac{\overline{\rho}-\widetilde{\widetilde{\rho}}(r)}{\overline{\rho}-\underline{\rho}} - F - \beta \cdot i(r) \geq \tfrac{(1-c)^2}{4} \end{aligned}$$

Of course, if $F \geq 0$, then the licensee's acceptance constraint imposes an upper bound on the royalty rate below c. The actual upper bound will depend on the cost and efficiency of the relationship-specific investments, e and i. On the other hand, recall from the analysis of the later stages that the royalty rate is bounded away from zero, otherwise the licensor's (and also the licensee's) investment is zero. Hence, the constraints of the problem define an interval of values of the royalty rate such that the transfer is feasible, in the sense of the parties undertaking the required investments and their respective restrictions being satisfied. Among these values, the licensor will choose the lowest value of r, since it may extract the licensee's profits above those in the outside option by means of the fixed payment.

Our purpose is not to characterize the optimal contract, but to show how increasing exchange rate uncertainty may prevent the transfer from taking place. For this reason next section presents numerical examples that illustrate how increasing the variance of the exchange rate, while holding its expectation constant, may make the set of feasible contracts empty.

3 Numerical examples

We now proceed to analyze the model for specific realizations of the parameter values. Recall that the demand function is $p = 1 - q$. Let us assume that costs are $c = \frac{1}{4}$ and $c_F = \frac{2}{5}$. The licensee's cost if using the licensor's technology is $c(e, i) = c_F(1 - e \cdot i)$, with $e, i \in [0, 1]$. Further assume that $\alpha = \beta = \frac{1}{40}$. Assuming that the exchange rate variable follows a distribution $U[\underline{\rho}, \overline{\rho}]$, we consider values of $\overline{\rho}$ and $\underline{\rho}$ such that $E\rho = 1$. We will see that increasing the width of the interval –and therefore the variance of the distribution– will eventually make the transfer of the technology impossible, since there will be no royalty rate that allows for the transfer of the technology.

First, if there was no uncertainty, the licensor would choose in the final stage $e = 1$ as long as $r \geq \frac{1}{8}$, provided that $i = 1$. Then, the licensee would choose in the previous stage $i = 1$ whenever $r \leq \left(1 - \frac{c_F}{2}\right) - \frac{2\beta}{c_F}$, which in our case, given the selected parameter values, implies $r \leq 0.675$. Furthermore, in order for the licensee's acceptance constraint to hold in the first stage, anticipating that $e = i = 1$, it must be the case that $r \leq 1 - \sqrt{(1-c)^2 + 4\beta}$, which given our parameter values translates into $r \leq 0.1861$.

Table 1. Feasible royalty rates for different interval widths

$[\underline{\rho}, \overline{\rho}]$	r
$[0.95, 1.05]$	$[0.1295, 0.186]$
$[0.90, 1.10]$	$[0.1345, 0.186]$
$[0.80, 1.20]$	$[0.1475, 0.186]$
$[0.70, 1.30]$	$[0.1720, 0.186]$
$[0.67, 1.33]$	$-$

Table 1 displays the set of feasible royalty rates for distributions $U[\underline{\rho}, \overline{\rho}]$, with $\underline{\rho} < 1 < \overline{\rho}$ and $E\rho = 1$. Notice that as we increase the width of the interval, holding the rest of the parameters constant, the interval of feasible royalty rates shrinks. This is because lowering the value of $\underline{\rho}$, while holding $E\rho$ constant increases the probability of the parties choosing zero investments, which lowers the value of the technological transfer to both parties. If the variance of the exchange rate variable is high enough, the transfer can not be implemented, as Table 1 shows. For the specific parameter values that have been chosen, the transfer can not be implemented for $\underline{\rho} < 0.672$, provided that $E\rho = 1$.

4 Conclusions

We have presented a model to analyze the effects of exchange rate uncertainty on a firm's technological imports. The efficient transfer of the technology requires the undertaking of complementary relationship-specific investments by both the licensor and the licensee. Considering payments that include a fixed fee and/or a royalty, an increase in the variance of the exchange rate variable could make the set of payments that implement the transfer empty.

This result arises because exchange rate variations occur in the interim between the licensor and the licensee's specific investment decisions. Since the licensor may make its investment decision conditional on the realization of the exchange rate, if the range of variation of this variable increases, the probability of the licensor choosing a zero level of investment increases, which calls for a higher royalty rate to restore the incentives of the licensor. This reduces the licensee's expected return on its relationship-specific investment, thus reducing its incentives to invest, which puts downward pressure on the royalty rate. If the range of variation of the exchange rate is wide enough, even if the expected exchange rate remains constant, there may may be no royalty rate –combined with a non-negative fixed fee-, that both parties find acceptable in order to transfer the technology.

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