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To cite this article: José Azevedo-Pereira, Gualter Couto & Cláudia Nunes (2013) Some results on relocation policies, The European Journal of Finance, 19:7-8, 779-790, DOI: 10.1080/1351847X.2011.606991

To link to this article: https://doi.org/10.1080/1351847X.2011.606991

Published online: 05 Mar 2012.

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Some results on relocation policies

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In this paper, we derive general results concerning optimal relocation policy under some assumptions. We consider a firm that is located in a specific location, producing at a certain level of efficiency. With time, the firm can decide to change its location to a new and more efficient site, paying relocation costs. Moreover, we assume that these new sites become available according to a Poisson process, and that the levels of efficiency improvement inherent to each one of these sites are random variables. With this framework, we characterise certain parameters of the optimal relocation policy. In particular, we characterise the expected relocation time and we prove that it depends on the distribution of the level of efficiency improvement only through an expected value. Therefore, the optimal policy shows a kind of robustness in terms of the stochastic assumptions of the problem, which has a major impact in the application of relocation policies. In addition, we also characterise the optimal relocation time. Impacts on the final results driven by the characteristics of the firm’s original location site, the market environment and the way in which risk is modelled are studied numerically. The overall results are in line with economic intuition.

Keywords: finance; relocation; project scheduling; real options; optimal timing; Erlang distribution

1. Introduction

According to the World Commission on the Social Dimension of Globalization (2004), the net inflows of foreign direct investment (measured in gross domestic product percentage) doubled in the period 1970–1990, whereas from 1991 to 2000, it had a growth of almost six-fold. Currently, globalisation is a hot issue especially in developed economies, as business performance is dramatically stipulated by the international competitiveness. Thus, the interest for locations with economic attractiveness has increased abruptly in recent years.

All potential locations are geographically known. However, this does not mean that every location is available in economic terms. Some potential locations are not effectively accessible due to political and environmental reasons, others because the technology available at present time cannot be rationally used by the workforce on hand or because they are difficult to access. The economic environment changes continuously at these and other levels that are relevant to the relative economic attractiveness of the different location sites. In the course of time, new sites become known and accessible, and eventually more efficient.

The interest in the economic facilities location problem is recent (end of last millennium), as the number of publications on the topic show. For example, Motta and Thisse (1994), Cordella and
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But all these studies focus mainly on the outcomes of risk versus return, rather than on the decision to move from one location to another. The relocation decision can be seen as an option (with specific value), and thus this problem can be analysed in the real options framework. But, as pointed by Sleuwaegen and Pennings (2006), the relocation issue has not been much explored.

Anyway, the decision about the relocation of a firm requires an accurate analysis, as relevant relocation costs can be involved. In fact, the relocation issue can be stated as a decision problem, as the firm has to consider, on the one hand, the benefits that will be the outcome from the relocation to a new and more efficient location, and, on the other hand, the costs inherent to the relocation (McDonald and Siegel 1986; Dixit and Pindyck 1994).

Efficiency will be the prime factor in identifying and distinguishing eventually interesting locations. High levels of efficiency will turn into more outputs with the same level of input (i.e. caused by the workforce’s technical competence growth) or to use lower levels of input to generate the same output (i.e. due to lower wages). Either way, the average cost of production will be smaller. We note that in the adoption of new technologies a similar modelling approach was used by Farzin, Huisman, and Kort (1998), Huisman (2000) and Huisman and Kort (2003).

The question that we address in this paper can also be addressed in the context of technology adoption, as the mathematical assumptions and models are the same. For example, Kwon (2010) found a similar situation in the optimal policy in the highly volatile environment regarding the disc drive industry, where it is difficult to calculate the optimal time to invest or quit because of the uncertainty in future demands. Cho and McCardle (2009) investigated the role of technological dependence on the adoption of multiple types of new technologies. They found that the timing of adoption is strongly influenced by the economic dependence and by the firm’s expectations about future technological changes. In accordance with our findings, a large amount of fixed cost occurs upon the adoption of a new technology, which becomes a sunk cost since technology choice is irreversible. Thus, economies of scale arise when the firm makes a single adoption with a significant improvement instead of making multiple incremental adoptions for the same aggregate level of improvements. Otherwise, improvements in each type of technology may will lead to a reduction in production cost in an additive manner. Finally, like in our assumptions, Liski and Murto (2006) found a relationship between factor market volatility and technology overlap: efficient new technology entry rate exceeds old technology exit rate under sufficient volatility. We have the same argument at the new locations available for the decision process.

In this paper, we address the relocation problem, following a real options approach. In order to do so, we need some mathematical formulation and probability assumptions that we describe in the following sections. But before we enter into specific details, we provide an informal description of the problem that we will tackle.

We consider a risk-neutral firm facing the following environment: information on new, potentially more efficient locations arrive randomly in time. The efficiency inherent to each (new and potentially efficient) location is also a random variable, and therefore the firm faces a stochastic environment with two levels of uncertainty: one about the moments in which new (and more efficient) sites will become available; and the other regarding the level of efficiency improvement inherent to each one of these new, yet to be known, potential locations. Thus, each time that a
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location becomes available, the firm has to decide if it relocates (paying a sunk cost investment \( I \), but producing at a higher level of efficiency). The optimal decision is then a balance between these two opposite forces.

The optimal policy for the firm in terms of relocation policy clearly involves the following variables:

- **Optimal relocation level:** level of efficiency of the new location that triggers the decision of relocation of the firm.
- **Optimal relocation time:** time at which the firm decides (optimally) to relocate.

Furthermore, in the framework that we consider in this paper (of uncertainty of the firm’s stochastic environment), the optimal relocation time is a random variable. Therefore, one wishes to derive its distribution or, at least, its moments (specially its expected value).

The remainder of the paper is organised as follows. Section 2 presents the model of a firm tackling the relocation decision and facing a stochastic environment, where information about new potentially superior locations is modelled according to a stochastic process. Using the classical framework of Dixit and Pindyck (1994), we present the decision problem associated with the relocation decision. Taking into account uncertainties related to (1), the speed at which new, more efficient locations will become known and (2) the rate of increase in the corresponding efficiency; in Section 3, we present the major result of the paper that extends all previous results concerning relocation problems; in Section 4, we particularise this result for the Erlang case and we derive the expected value for the time until relocation. Section 5 provides the corresponding numerical results and the parallel economic rationale.

Finally, a word about the notation used in this paper and notably concerning random variables. If \( X \) is a random variable, we denote its distribution function by \( F_X(\cdot) \). Moreover, \( \mathbb{E}[X] = \int u \, dF_X(u) \) denotes its expected value, whereas \( \mathbb{E}[X^2] = \int u^2 \, dF_X(u) \) is its second-order moment and \( \text{Var}[X] \) its variance, with \( \text{Var}[X] = \mathbb{E}[X^2] - \mathbb{E}^2[X] \). Finally, i.i.d. means independent and identically distributed.

2. **Stochastic formulation**

In this section, we introduce the mathematical formulation of the relocation problem that we address in the paper.

Along the paper, we assume a risk-neutral firm, with a constant discount factor, \( r \), like in Dixit and Pindyck (1994) and we let \( \pi(\cdot) \) denote the cash flow of the firm. We analyse a dynamic model with an infinite planning horizon and we assume that when the firm chooses a new location, it incurs a sunk cost investment \( I \).

We assume that new and more efficient locations become available to the firm according to a Poisson process \( N \), with rate \( \lambda \), with \( N \) being independent of the firm. Furthermore, we let \( \{ U_i, i \in \mathbb{N} \} \) denote a sequence of i.i.d. random variables, where \( U_i \) denotes the degree of efficiency improvement inherent to the \( i \)th location that becomes available to the firm, with \( \{ U_i, i \in \mathbb{N} \} \) being also independent of the Poisson process \( N \).

Moreover, \( \theta(t) \) is the efficiency of the firm at the best location available at time \( t \), such that for \( s \leq t, \theta(s) < \theta(t) \) (i.e. we consider only locations that improve, in some degree, the efficiency). Finally, we assume that the efficiency of the firm before any relocation is simply \( \theta(0) = \theta_0 \), so that in fact we are assuming that the firm chose its initial location in an optimal way; this assumption can be easily relaxed.
It is clear from the description of the problem that the decision to relocate can be stated as a capital budgeting decision problem. Each time a new (and more efficient) location becomes available, the firm has to decide if it stays in the same place (avoiding an investment cost, but loosing the opportunity to produce more efficiently) or if it changes to the new location. Therefore, the firm has to decide between continuing in the present location or stop, and move to a new location. This decision strongly depends on the relationship between the current efficiency of the firm and the efficiency that it will achieve in the new location, balanced by the relocation cost. In order to justify a change in location, the corresponding efficiency gains need to overcompensate the resulting relocation costs.

Let \( \theta^* \) denote the value of the efficiency that triggers a relocation, such that if \( \theta(t) > \theta^* \), the firm decides to invest in this new location, whereas if \( \theta(t) \leq \theta^* \), the optimal decision is to stay in its current site and wait for other locations to become available. In addition, we let \( T^* = \inf\{t \geq 0 : \theta(t) \geq \theta^* \} \), so that if the firm acts optimally then \( T^* \) is the random variable that denotes the optimal time of relocation.

We remark that, as \( T^* \) is a continuous non-negative random variable, then it follows that \( E[T^*] = \int_0^\infty (1 - P(T^* \leq t)) \, dt \) (Ross (1996)). Therefore, it follows that

\[
E[T^*] = \int_0^\infty (1 - P(T^* \leq t)) \, dt = \int_0^\infty P(\theta(t) < \theta^*) \, dt
\]

\[
= \frac{1}{\lambda} + \int_0^\infty \left[ \sum_{k=1}^{\infty} \left( \int_0^{\theta^* - \theta_0} f_{\sum_{n=1}^k u_n}(x) \, dx \right) \frac{e^{-\lambda t} (\lambda t)^k}{k!} \right] \, dt
\]

\[
= \frac{1}{\lambda} \left( 1 + \sum_{k=1}^{\infty} F_{\sum_{n=1}^k u_n}(\theta^* - \theta_0) \right),
\]

where \( f_{\sum_{n=1}^k u_n}(\cdot) \) (\( F_{\sum_{n=1}^k u_n}(\cdot) \)) denotes the density function (distribution function) of the sum of i.i.d. random variables \( U_1, U_2, \ldots, U_k \). Using similar arguments, one can prove that

\[
E[(T^*)^2] = \frac{2}{\lambda^2} \left( 1 + \sum_{k=1}^{\infty} F_{\sum_{n=1}^k u_n}(\theta^* - \theta_0) \right).
\]

We call the value \( \theta^* \) the optimal relocation level and \( T^* \) the optimal relocation time. In this paper, we assume the existence and uniqueness of \( \theta^* \).

If the firm decides to change its current location, then it means that for all \( \theta > \theta^* \), the value of the firm, \( F(\cdot) \), is simply given by \( V(\theta) - I \), where \( V(\cdot) \) denotes the value of the firm if it stays in the same location forever. On the other hand, if the firm does not change its current location then the value of the firm for \( \theta < \theta^* \) is given by

\[
F(\theta) = \frac{\pi(\theta_0)}{r + \lambda} + \frac{\lambda}{r + \lambda} \left[ \int_{\theta - \theta^*}^{\theta^* - \theta} F(\theta + u) \, dF_U(u) + \int_{\theta^* - \theta}^{\infty} (V(\theta + u) - I) \, dF_U(u) \right],
\]

where the first component corresponds to the present value of the payoffs inherent to the initial location; the first element in the second component represents the value of the real option to relocate production to a place where a higher level of efficiency will be achieved; and the second element in the second component corresponds to the net present value of the firm after moving to
the new location – disbursing the investment cost, $I$ and benefiting from the increase in net cash flows granted by the increased level of efficiency.

We note that Equation (3) can be rewritten as follows:

$$F(\theta) = \frac{\pi(\theta_0)}{r + \lambda} + \frac{\lambda}{r + \lambda} \left[ \mathbb{E}[F(\theta + U) | U < \theta^* - \theta] P(U < \theta^* - \theta) \right. \right.$$

$$\left. + \mathbb{E}[V(\theta + U) - I | U \geq \theta^* - \theta] P(U \geq \theta^* - \theta) \right].$$ (4)

3. General result

In this section, we present one of the major contributions of this paper that extends results presented by Farzin, Huisman, and Kort (1998), Huisman and Kort (2003) and Azevedo-Pereira, Couto, and Nunes (2010).

**Theorem 3.1** The optimal relocation level $\theta^*$ is the solution of the following equation:

$$(r + \lambda)V(\theta^*) - \lambda \mathbb{E}[V(\theta^* + U)] = \pi(\theta_0) + rI,$$ (5)

and therefore $\theta^*$ depends on the distribution of $U$ only through the expected value $\mathbb{E}[V(U)]$.

*Proof* If in Equation (4) we set $\theta = \theta^*$, then we get the following expression for the value of the firm at the optimal switching level:

$$F(\theta^*) = \frac{\pi(\theta_0)}{r + \lambda} + \frac{\lambda}{r + \lambda} \left( \mathbb{E}[V(\theta^* + U)] - I \right)$$ (6)

because $P(U \geq 0) = 1$, and thus $F(\theta^*)$ depends on the distribution of the jump size $U$ through an expected value, as stated in the theorem. Equation (5) follows as $F(\theta^*) = V(\theta^*)$.

The consequence of this result is quite powerful. For instance, if $V(\cdot)$ is a polynomial function of order $k$, then Theorem 3.1 states that the optimal switching level depends at most on the first $k$-order moments of the random variable $U$.

Theorem 3.1 shows a certain robustness of the optimal relocation policy in terms of the density distribution of the increments of the efficiency, with major implications in the modulation issue.

For the sake of illustration, we assume the following Cobb–Douglas production function:

$$\pi(x) = \phi x^2,$$

where $\phi$ is the parameter associated with the inputs used in the production function (as considered in Farzin, Huisman, and Kort (1998)), so that the value of the firm after relocation is

$$V(\theta) = \frac{\phi \theta^2}{r}.$$ (7)

We remark that with this assumption, Huisman (2000) has already derived results concerning $\theta^*$, the value of the firm $F(\cdot)$ and $T^*$ when $U$ has degenerate, uniform or exponential distribution. Azevedo-Pereira, Couto, and Nunes (2010) derived also results when $U$ has truncated exponential and gamma distribution (in this last case, they consider a gamma distribution with parameters 2 and $k$).
Then, Theorem 3.1 allows one to conclude that as long as \( E[U] \) and \( E[U^2] \) are constant, any distribution for \( U \) holds the same optimal relocation level. In fact, it follows that

\[
E[V(\theta^* + U)] = \frac{\phi((\theta^*)^2 + E[U^2] + 2\theta^*E[U])}{r}
\]

and thus, according to Theorem 3.1, the optimal switching level depends on the distribution of \( U \) only through its expected value and variance. Moreover, \( \theta^* \) is the solution of the following equation:

\[
\phi r(\theta^*)^2 - 2\lambda \phi E[U] \theta^* - (r\pi(\theta_0) + \lambda \phi E[U^2] + r^2 I) = 0. \quad (8)
\]

If we let 

\[
a = \phi r, \quad b = \lambda \phi E[U] \quad \text{and} \quad c = r\pi(\theta_0) + \lambda \phi E[U^2] + r^2 I
\]

then \( \theta^* \) is given by

\[
\theta^* = \frac{b + \sqrt{b^2 + ac}}{a}. \quad (9)
\]

For particular instances of distributions for \( U \), the derivation of the optimal relocation level is simply the computation of Equation (9), with \( a, b \) and \( c \) computed accordingly. For example, if \( U \sim \text{Exp}(1/u) \), where \( u \in \mathbb{R}^+ \), then \( E[U] = u \), whereas \( E[U^2] = 2u^2 \), so that \( b = \lambda \phi u, c = r\pi(\theta_0) + 2\lambda \phi u^2 + r\lambda I \). Consequently,

\[
\theta^* = \frac{u\lambda \phi + \sqrt{\phi [r^2(\pi(\theta_0) + Ir) + u^2\lambda(2r + \lambda)]}}{r\phi}, \quad (10)
\]

which matches with the corresponding results of Huisman (2000).

\[ \square \]

4. Optimal policy in the Erlang case

In this section, we assume that the increase in the efficiency is modelled as an Erlang distribution and we derive the optimal policy for this case.

An Erlang distribution with parameters \( K \) and \( K/\mu \) can be seen as the sum of \( K \) i.i.d. exponential random variables, with parameter \( K/\mu \), Ross (2005). We note that the investment decisions are subject to several risk factors that are eventually independent. Therefore, in modelling these type of problems, it makes sense to introduce distribution functions that enable the analytical treatment of more than one state variable, in order to approximate the modelling exercise to corporate reality.

We say that \( U \) has an Erlang distribution with parameters \( K \) and \( K/\mu \) if its density function is as follows:

\[
f_U(x) = \frac{K}{\mu e^{-K/\mu}} \frac{(k/\mu x)^{K-1}}{(K-1)!}, \quad x \in \mathbb{R}^+
\]

where \( \mu > 0 \) and \( K \in \mathbb{N} \), and we write, for short, \( U \sim \text{Erl}(K, K/\mu) \). We note that this is a special form of a gamma distribution, with an integer parameter \( K \).
For an Erlang distribution with these parameters, the two first-order moments are given by

\[ E[U] = \mu, \quad E[U^2] = \mu^2(1 + K^{-1}). \]

In view of Equation (10), with \( b = \lambda \phi \mu, \quad c = r \pi (\theta_0) + \lambda \phi ((K + 1)/K) \mu^2 + r^2 \lambda I \), we obtain the following expression for the optimal level:

\[ \theta^* = \frac{\mu \lambda \phi + \sqrt{\phi K^{-1}(Kr^2(\pi(\theta_0) + r) + \mu^2((K + 1) r + K\lambda)\phi)}}{r \phi}. \] (11)

In the following theorem, we provide the expected value of \( T^* \), the time until relocation. We skip the proof, as the results follows straightforward from Equation (1).

**Theorem 4.1**

\[ \mathbb{E}[T^*] = \frac{1}{\lambda} \left[ 1 + \sum_{j=1}^{\infty} \frac{K \gamma(jK, (K/\mu)(\theta^* - \theta_0))}{(jK)!} \right], \] (12)

where

\[ \gamma(a, b) = \int_0^b t^{a-1} e^{-t} \, dt \] (13)

is the lower incomplete gamma function.

### 5. Numerical illustration

In this section, we illustrate some of the results derived in the previous section, using particular instances of the Erlang distribution. In addition, we assume that the production function is as in Equation (7), and that the rate at which new locations become available is \( \lambda = 0.5 \). According to Theorem 3.1, the optimal relocation level depends on the distribution of the jumps \( U \) only through the first two moments, \( E[U] \) and \( E[U^2] \).

For the sake of numerical illustration, we assume the following values for the parameters of interest: output price \( p = 1000 \), input price \( w = 250 \), discount rate \( r = 0.05 \), sunk cost of investment in a new location \( I = 10,000 \), here for the sake of the illustration assumed to be constant in time and independent of the relocation site) and initial efficiency \( \theta_0 = 1 \). Thus, Equation (7) takes the following known form:

\[ V(\theta) = 20,000 \theta^2. \] (14)

In the next table, we present the optimal relocation level for several instances of the shape parameter of the Erlang, \( K \) and the rate parameter, \( \mu \) (Tables 1 and 2). Notice that in these particular cases, the optimal relocation level depends more on \( \mu \) than on \( K \). For \( \mu = 0.1 \), the first two moments range from 10 and 200 (for \( K = 1 \) up to 100 and 11,000 (for \( K = 10 \)), whereas for \( \mu = 10 \), they

| Table 1. Behaviour of \( \theta^* \) for different instances of the Erlang distribution. |
|-----------------|-----|-----|-----|-----|-----|-----|-----|
| \( K \)        | 1   | 2   | 3   | 4   | 5   | 10  |
| \( \mu = 0.1 \) | 2.643 | 2.628 | 2.623 | 2.620 | 2.619 | 2.616 |
| \( \mu = 10.0 \) | 209.551 | 207.245 | 206.465 | 206.073 | 205.837 | 205.364 |
Table 2. Behaviour of $\theta^*$ for different instances of the Erlang distribution, with constant expected value.

<table>
<thead>
<tr>
<th>$K$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu$</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>$\theta^*$</td>
<td>2.643</td>
<td>4.470</td>
<td>6.421</td>
<td>8.416</td>
<td>10.431</td>
<td>20.607</td>
</tr>
<tr>
<td>$\mu$</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>$\theta^*$</td>
<td>209.551</td>
<td>414.480</td>
<td>619.377</td>
<td>824.266</td>
<td>1029.150</td>
<td>2053.570</td>
</tr>
</tbody>
</table>

Figure 1. Behaviour of the optimal relocation level as a function of the output and the input prices.

range from 0.1 and 0.2 (for $K = 1$) up to 1 and 1.1 (for $K = 10$). In addition, for the case $\mu = 10$, the first two moments are of the same order, whereas for $\mu = 0.1$, the second moment is at least one order larger than the first moment.

Finally, in order to check the influence of the second moment, we present values regarding the optimal relocation level for instances of the Erlang distribution with the same expected value (but different second-order moment), which is in accordance with the result of Theorem 3.1. Thus, differences on $\theta^*$ are to be expected as the value of the firm is a quadratic form, and therefore $\theta^*$ depends both on the first- and second-order moment.
Next, we present numerical results concerning the optimal relocation level when we impose changes in certain parameter values. In particular, we analyse the effect on the optimal relocation level, $\theta^*$, of the following parameters: output price $p$, input price $w$, investment cost $I$, discount rate $r$ and initial efficiency $\theta_0$. We consider three instances of the Erlang distribution with parameters $K$ and $\mu = 0.1$, with $K = 1, 3$ and 5. See Figures 1–3.

Higher levels of output prices lead naturally to decreases in the value of the option to delay an investment. Therefore, increases in output prices lead to decreases in optimal relocation levels (Figure 1). In effect, the level of efficiency that triggers a change in location needs to be increased in order to compensate the gross margin reduction, induced by the decreases in output prices.

On the contrary, higher levels of input-related costs lead naturally to increases in the value of the option to delay an investment. Therefore, increases in input prices lead to increases in optimal...
relocation levels (Figure 1). In result, the level of efficiency that triggers a change in location needs to be increased in order to also compensate the gross margin reduction, induced by the increase in input prices.

The relationship between optimal relocation levels and investment costs follows a similar pattern (Figure 2) and seems to be essentially an increasing linear function of the level of the expected increase in investment costs. Increases in investment costs need to be properly compensated by efficiency increases in order to justify changes in location.

We also present a plot concerning the behaviour of the optimal relocation level as a function of the discount rate (Figure 2). Reduced discount rate levels mean smaller time value of money and consequently, a small potential loss for postponing the decision to relocate. In contrast, very high discount rate levels imply untenable delaying costs. The convex shape is in accordance with the economic rationale related to the valuation of all interest rate products. Furthermore, we note that the difference in the optimal relocation level for the three cases (Erlang distribution with parameters 1, 3 and 5) is negligible and cannot even be noticed in Figure 2.

Finally, we present a plot concerning the behaviour of the optimal relocation level as a function of the initial efficiency. Higher levels of initial theta lead naturally to increases in the value of the option to delay an investment. Therefore, increases in initial values of the actual efficiency lead to increases in optimal relocation levels (Figure 3). In effect, the level of efficiency that triggers a change in location needs to be increased in order to compensate the loss of actual efficiency in the current location.

6. Concluding remarks

The problem of relocation is specially relevant, given its socio-economic implications, in the present period of globalisation, and it is transversal to the whole society. The interested public is a large spectrum of social actors. Entrepreneurs/businessmen are concerned with the impacts on the companies’ results, whereas employees think about the access to working places and its implications regarding the choice of their place of residence. Finally, public entities that are
responsible for the promotion of policies that lead to economic and social welfare and to society’s sustained development. They are connoisseurs of the problem’s magnitude, as much as employees and businessmen, and tend to understand its consequences. Therefore, they are able to take the conducting measures to turn obvious its negative repercussions and enhance the positive ones.

One rationale of this work is to suggest that application of models and techniques derived from theoretical industrial organisation now allows a reconsideration of economic geography, and that it is now time to attempt to incorporate the insights of the long, but informal, tradition in this area into formal models with real options analysis. Our paper develops an illustrative model designed to give an important answer on the relocation problem: why and when does manufacturing become relocated in new regions.

Other things being equal, Krugman (1991) referred that the preferred sites for production location will be those with relatively large nearby demand, since producing near one’s main market minimises transportation costs. Other locations will then be served from these centrally located sites. Maybe this is the reason for why in kinds of productivity gains, but we need the answer to why.

What we shall see is that it is possible to develop a very simple model of geographical relocation of manufacturing based on the interaction of efficiency gains and relocation costs. This is perhaps not too surprising, given the kinds of results that have been emerging in the recent literature about new technologies adoption (Huisman (2000)).

One of the key points in the relocation problem is its optimal timing to give the answer to why moving. As we mentioned previously, this timing is significantly affected by the uncertainties related to both the expected rhythm that characterises the arrival of information regarding the availability of new, more efficient location sites, and the degree in efficiency improvement from one location to another. The focus of the article is on the perceived increase in efficiency needed to justify the decision to relocate from one place to another. Using a stochastic framework, we have analysed the problem of the optimal timing for the relocation of a firm to move its production site. Given the specific characteristics of the relocation decision, and unlikely any other work that we are aware of in this field, we note that the optimal relocation level depends on the distribution of $U$ (the increase in the efficiency of a new location) only through an expected value. Finally, numerical outcomes suggest that the results of our model are in accordance with the economic rationale.

Acknowledgements

The research was supported in part by Programa Operacional ‘Ciência, Tecnologia, Inovação’ (POCTI) of the Fundação para a Ciência e a Tecnologia (FCT), cofinanced by the European Community fund FEDER and the projects UTAustin/MAT/0057/2008, PTDC/EIA-CCO/098910/2008 and UTA-CMU/MAT/0006/2009.

Note

1. In order to derive simpler algebraically expressions, we assume these parameters, so that, in particular, the expected value is $\mu$.

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