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Empfohlene Zitierung / Suggested Citation:
Mendi, P. (2007). Contractual Implications of International Trade in Tacit Knowledge. *Applied Economics*, *39*(9), 1173-1183. https://doi.org/10.1080/00036840600592817

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Journal:	*Applied Economics*
Manuscript ID:	APE-04-0136.R1
Journal Selection:	Applied Economics
Date Submitted by the Author:	08-Aug-2005
JEL Code:	O33 - Technological Change: Choices and Consequences|Diffusion Processes < O3 - Technological Change|Research and Development < O - Economic Development, Technological Change, and Growth
Keywords:	know-how, contract duration, technical assistance

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Abstract

This paper searches for evidence on the additional difficulty the parties have in contracting for the transfer of know-how relative to the transfer of patented technology. A sample of contracts for the acquisition of technology by Spanish firms in 1991 is analyzed to find a positive relationship between contract duration and the likelihood of transferring know-how in unaffiliated transfers. It is also found that technical assistance is bundled together with the transfer of know-how, suggesting that the parties try to mitigate opportunistic behavior on the licensor's side.

1. Introduction

The transmission of tacit knowledge has some problems inherent to it that are not present in the transfer of other types of technology. These problems stem from the fact that it is uncodified knowledge, which allows neither contracts being written contingent on technology characteristics nor legal protection of technology. This characteristic causes moral hazard problems on both sides, first described in Arrow (1962). Moral hazard problems are less acute in the case of codified, legally protected technology. On the one hand, codification implies that the relevant characteristics of the technology can be described, which allows the parties to write contracts contingent on them. On the other hand, legal protection against imitation dramatically limits potential moral hazard problems both on the licensor and on the licensee's side.

This paper studies the determinants of the transfer of patented technology and know-how and the role of the provision of technical assistance services in the transfer of tacit knowledge. The empirical analysis is carried out using a sample of technology-importing contracts signed by Spanish firms in 1991. One of the findings of the paper is that while contract duration has a positive effect on the probability of transmission of know-how in unaffiliated transfers, it has no effect on the probability of a patent being transferred. Contract duration is defined as the number of years the parties agree the relationship to last at the time of signing the contract. Another finding is that the provision of technical assistance eliminates the effect of contract duration on the likelihood of transferring know-how. It will be argued that this is consistent with technical assistance being used as a safeguard against the licensor behaving opportunistically.

The analysis of international technology transfer is important for its impact on productivity and growth, as found, at a macroeconomic level, in Attella and Quintieri (2001), Engelbrecht (1997) or Frentzen (1998). Descending to a microeconomic level, although several studies, such as Anton and

Yao (1992, 1994) or King (2003) analyze theoretically the transfer of unprotected technology, the empirical evidence on the actual licensing procedures is very scarce. Among the few studies using transaction-level data, Caves et al (1983) summarize the difficulties faced when transferring technology, and Anand and Khanna (2000) find inter-industry differences in contractual practices. Kim (2004) finds that the strength of intellectual property protection and prior licensing activity, among other factors, increase the propensity of US firms to license their technologies. Macho-Stadler et al (1996) and Mendi (2005) use the database employed in this article, although the focus in these articles is on explaining scheduled payments.

Contract duration has not been the main object of theoretical or empirical studies on contracts for the international transmission of technology. The temporal dimension of the agreement has been typically overlooked in the literature, focusing on difficulties to contract due to asymmetric information or the risk inherent to the transmission of the technology, but never considering the case of the relationship lasting for several periods. Thus, one of the contributions of this paper is to explicitly consider the temporal dimension of contracts and to analyze whether contract duration varies with the type of technology to be transferred.

In this paper, contract duration is considered to be exogenous, and determined by how long will the technology be useful before its obsolescence. It is assumed that licensors sell different product and/or process technologies with different expected remaining useful lives. Once these useful lives expire, technologies become obsolete and therefore, worthless. These remaining useful lives at the time of contracting actually determine contract duration.

The estimated effect of contract duration also suggests that the transfer of know-how is much more difficult than that of patented technology. This way, duration affects the likelihood of know-how being transferred because longer contracts reduce the scope for moral hazard on both sides. Hence, if the relationship is scheduled to be short-lived, the temptation of the parties to breach the contract is

greater than in the case of longer relationships (see Klein, 1996). Foreseeing this, the parties may be unable to sign an agreement in the first place, and therefore, the observed distribution of contract duration in those contracts that include the transmission of know-how will be skewed to the right.

Regarding the provision of technical assistance services to facilitate the transmission of tacit knowledge, Arora (1996) presents evidence of complementary inputs being bundled together with the transfer of know-how, arguing that they mitigate moral hazard on the licensor's side. In the presence of potential moral hazard problems on the licensor's side, technical assistance can be a safeguard against this opportunistic behavior. It can be regarded as commitment by the licensor to provide the licensee with the first-best level of technology, as long as providing technical assistance is costly to the licensor of the technology. Arora (1996) also finds that patents are bundled together with know-how, a result not found in the present paper.

However, a positive relationship between the transfer of know-how and the provision of technical assistance should be interpreted with caution, since, by the non-codifiability of know-how, the provision of technical assistance is the natural way to transfer tacit knowledge, independently of any moral hazard problems. The result obtained in this paper is that transfers of know-how, but not of patents, are associated with the provision of technical assistance. The additional result that technical assistance eliminates the effect of duration on the likelihood of transferring know-how constitutes further evidence consistent with technical assistance mitigating moral hazard problems on the licensor's side.

The organization of the paper is as follows. Section 2 discusses how contract duration may affect the transfer of know-how and why the parties may be interested in including technical assistance in the agreement. Section 3 describes the data, which will be analyzed in Section 4. Finally, Section 5 summarizes the main conclusions from the empirical analysis carried out in this paper.

2. Technology trade, contract duration, and the provision of technical assistance

This section discusses how the transfers of patented technology and of know-how are differently affected by moral hazard problems. Furthermore, it will be discussed how contract duration may alter the incentives of the parties to behave opportunistically. The hypotheses to be tested in the empirical section will also be presented.

Patented technology and know-how differ substantially in their tacitness. The former type of technology is codified knowledge, which allows for its description and delimitation of what is included and what is not included in the patent, and therefore, what is and what is not legally protected against imitation. Furthermore, the possibility of describing the object of a patent permits that contracts be written based on the characteristics of patented technology, since it is possible for third parties to verify these characteristics. By contrast, know-how is tacit, uncodified knowledge. This characteristic prevents the parties from writing contracts based on technology characteristics, which are non verifiable by third parties. This tacitness also impedes that know-how receive legal protection against imitation.

There is less room for potential moral hazard problems in the transfer of a patent than in the transfer of know-how. In the latter type of transfers, the licensee may renege on payments, and the licensor may provide a suboptimal type of technology, see for instance Choi (2001). If this threat is serious enough, in some cases the agreement might not be signed at all. In other cases, the parties will be forced to include safeguards in order to actually sign the contract.

In this paper, contract duration refers to what the parties expect the relationship to last given their information at the time of signing the contract. This will not always be equal to actual contract duration, since some contracts may be terminated early. Incentives to deviate from honest behavior differ with contract duration. If the parties sign a short-term contract, they have a smaller incentive to cooperate in the successful implementation of the technology than in the case of a longer relationship, since the opportunity cost of breaching the contract is greater the longer the remainder of the

relationship. Of course, for this effect to exist, there must be some way the non-deviant can punish the deviating firm. In the case of the licensee deviating by reneging on its payments due, the licensor can license another firm, thus reducing the original licensee's profits, a reduction that will be increasing in contract duration. Similarly, if the licensor does not provide the first-best technology to the licensee so as to save in costs, the opportunity cost to the licensor is the fact that it is receiving lower revenues. This opportunity cost is also increasing in contract duration.

Legal protection of technology is crucial in determining how profitable contract breaching is, and thus, to analyze whether contract duration will have any effect at all in the likelihood of observing specific types of technology being transferred. If legal protection of the technology is strong, for instance in a patent licensing contract, the temptation to cheat is reduced. In this case, contract duration should not be a factor in determining how likely to be signed these contracts are, and therefore, its effect on the likelihood of observing the transfer of a patented technology should be null.

By contrast, this same argument suggests that the likelihood of know-how being transferred should be non-decreasing in contract duration. For some short-term contracts, opportunistic behavior by either party may prevent the parties from actually signing the contract. The incentives to not behaving opportunistically increase in contract duration, since the profit from continuous cooperation more likely exceed the instantaneous gain from deviation.

This double prediction is precisely what will be tested in the empirical section. Using data from contracts for the imports of technology by Spanish firms in 1991, it will be analyzed whether contract duration affects the likelihood of observing a patent and know-how. If moral hazard inherent to the transfer of know-how is an issue, then duration should positively affect the likelihood of know-how but should have no effect in the transfer of a patent. However, evidence on the existence of such relationship cannot be regarded as a definitive proof of a direct causality effect of duration on the likelihood of transferring know-how, since the observed correlation could well be via a selection effect.

Furthermore, the available data does not allow the empirical analysis from ruling out alternative explanations. Indeed, a positive effect of duration may just come from the fact that the transmission of know-how takes longer to be carried out.

Related to the problems inherent to the transfer of tacit knowledge, the provision of technical assistance can be a way to ensure that the licensor indeed supplies the first-best level of technology. In some sense, see Arora (1992, 1996), it acts as a commitment device, if the provision of technical assistance is costly to the licensor. What will be analyzed empirically is whether technical assistance is more likely to be present in transfers of know-how than of patents. Additionally, it will be tested whether or not contract duration affects differently the likelihood of including know-how, depending on the inclusion of technical assistance in the original agreement. If the provision of technical assistance indeed solves the moral hazard problems on the licensor's side, conditional on moral hazard problems on the licensee's side being relatively less important, then duration should not affect the likelihood of transferring know-how in contracts where technical assistance is included. By contrast, in those contracts where technical assistance is not included, contract duration should still have a positive effect on the probability of transferring tacit knowledge. Evidence for this effect will also be searched for in the empirical section.

3. The data

The dataset is obtained after examination of the records of the Spanish Ministry of Industry. All Spanish firms that imported technology were required, up to 1992, to report the terms of the technology purchase. The importer of the technology had to file a form, named 'TE-30', with the 'Servicio de Información y Transferencia de Tecnología' (Technology Transfer Office), a branch of the Spanish Ministry of Industry. In some cases, in addition to this form, the firm included the actual

contract, although this was optional. This type of control is no longer allowed by the European Union, and thus filing was terminated in 1992.

The Spanish firm, which was the licensee in all cases, had to describe in this form some features of the technology being purchased or licensed. First, the licensee reported whether that technology could be classified as a product and/or a process technology. The Spanish firm also indicated whether or not the agreement included a transfer of a patent, a utility model (a minor invention also legally protected), know-how, an industrial design or software. In some cases, the contract includes the transfer of several of these technology types. Out these types of technology, know-how is the only one that constitutes tacit knowledge, since the rest of them are codified and receive some legal protection against imitation, whereas legal protection is strongest in the case of a patent. In the same form, the Spanish firm also reported whether the contract was a licensing contract, where only the right to use a given technology was purchased, or it was an actual sale, where the Spanish firm acquired ownership of the technology. In the empirical analysis, all the variables constructed using these items will be dichotomous, taking values zero or one, since what is observed is the Spanish firm reporting whether or not the contract includes the transfer of these technological characteristics.

Regarding information on the Spanish firm, in addition to the industry of its main activity, it reported its sales in the year before the filing of the form. Also included was information on what kind of linkages licensor and licensee had, if any. The licensee, when applicable, had to report the percentage of its equity owned by the licensor, or if both firms had a common parent. Using this information, the observations can be classified into affiliated and unaffiliated. Two parties are affiliated if either there is a direct participation of the licensor of 50% or more in the licensee's equity or if both firms have a common parent. The Spanish firm also reported whether it performed R&D, although there was no information on the percentage of sales devoted to this activity. Regarding the licensor's characteristics, both its industry and country appear on the form. The form also contains a licensee's estimate of

scheduled payments to be made during the initial five years of the contract, distinguishing between fixed and variable payments. If the relationship was scheduled to last longer than five years, the licensee was not required to provide an estimate of payments. The impact of some characteristics of the transferred technology on payment schemes has been analyzed in Mendi (2005).

Whenever the contract is filed together with the form, more variables are observable, by inspection of the contract clauses. In particular, contracts stipulate the duration of the agreement, which is the number of years the parties expect the relationship to last at the time of signing the contract. Thus, for those observations where the contract was filed together with the form, the duration variable just takes the value specified in the contract. For some cases in which only the form was filed, duration can be inferred by observing in what period scheduled payments stopped. In these cases, duration is the last year for which positive payments were scheduled. There are some observations for which duration is neither observed nor inferred, making duration missing in 27 occasions.

Concerning the sampling process, the Spanish Ministry of Industry followed no systematic criterion in the classification of the forms. They were literally stored in boxes as they were received and sent to the archives in a basement located in the central offices of the ministry, in Madrid. This suggests that there was no significant bias arising from the sampling procedure, which was to randomly select boxes and inspecting the forms contained in them. The sample size is conditioned by the fact that the author obtained permission only for two weeks to copy the contents of the forms manually.

Out of the 5168 forms filed in 1991, which are described in Pérez (1996), the sample used in the empirical section of this paper includes 165 observations. 212 observations were collected with a clear technological content, since they specified the transfer of a patent, a utility model, an industrial

design, know-how, or software (not for resale[1]). This criterion leaves out of the sample contracts where the technological content is less clear, for instance those where the licensee is just a software retailer. In addition to the 27 missing values of the duration variable, sales are not reported in 22 cases. This means that, out of the mentioned 212 observations with a clear technological content, only 165 observations are used in the empirical analysis[2].

Table 1 and 1b present selected characteristics of the contracts, classified by industry of the licensee. The data have been classified into five industry groups: Agriculture; Energy, Minerals, and Chemicals; Metal Transformation; Other Manufacturing and Construction; Services. These industry groups correspond to industries 0, 1-2, 3, 4-5, and 6-9 respectively, according to Spanish classification of industries (CNAE-74).

[Insert Tables 1a and 1b here]

As it can be seen in Table 1a, there is some variation across industries in technology characteristics. Most contracts made in Energy, Minerals and Chemicals include the transfer of know-how, whereas less than half of the contracts in Services, Other Manufacturing, Construction, or Agriculture include the transmission of this type of technology. By contrast, the proportion of contracts that include the transfer of a patent is highest in Agriculture, and in the remainder industry groups, it is below one third. This stresses the fact that patented technology, which has received significant attention in the Economics literature, represents a relatively small part of the international market for technology. This result also holds when total payments in transfers including a patent and not including one are considered.

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[1] Included in the sample are transfers of software only if it is to be used by the licensee. There are some contracts in the sample where the licensee merely acts as a software retailer. These transfers have been explicitly excluded from the final sample.

[2] In two cases, neither duration nor sales were observed.

The provision of technical assistance services is more frequent in Metal Transformation and Services, and rarely observed in Agriculture and Other Manufacturing and Construction. On the other hand, process technologies are prevalent in Services, and no contract in Agriculture fall into this category. In this paper, a given technology is considered to be of a process type if the licensee classifies it as a process but not product technology.

Table 1b summarizes information on other variables also employed in the empirical analysis. Unaffiliated transfers are prevalent in all industries, with Agriculture having the highest percentage, over 80%. This variable is also dichotomous, taking the value zero if unaffiliated, and one if the transfer is made between affiliated parties. The transfer of ownership is rarely observed in these contracts, less than 10% overall, implying that most contracts are indeed licensing contracts. Ownership is transferred about 15% of the times in Energy, Minerals, and Chemicals and in Metal Transformation, whereas in the remainder industries it is rarely transmitted. Duration, measured in years, is also highest in Agriculture, and in the neighborhood of five years in the case of the remaining industries, except for Services, which presents much shorter contracts on average. Finally, there is a high degree of heterogeneity across industries in the licensee's sales, measured in millions of Spanish pesetas with the average firm in Energy, Minerals and Chemicals being 20 times as big as the average firm in Agriculture. In the empirical analysis, the logarithm of this variable will be used.

4. Empirical evidence

This section presents some empirical evidence drawn from the sample of contracts described in the previous section. First, evidence is presented on the relationship between know-how, patents, and technical assistance. Then, the factors that determine the transfers of patented technology as well as know-how are analyzed. Finally, evidence on the role of technical assistance in the transfer of tacit knowledge is presented.

4.1. Transfers of patents, know-how, and provision of technical assistance services

Tables 2a, 2b, and 2c are cross tabulations of the indicators of the transfer of a patent, the transfer of know-how, and the provision of technical assistance services. First, Table 2a, which cross-tabulates indicators of the transfer of patents and know-how, shows that rarely is patented technology transferred together with tacit knowledge, only 17 out of 165 observations. The non-complementarity between these two types of technology is confirmed by the value of the Chi-squared test, which is statistically significant at the 5% level.

Tables 2b and 2c are aimed at providing evidence of whether technical assistance is likely to be bundled together with a particular type of technology. Table 2b presents the cross tabulation of know-how and technical assistance. It is clear that the transfer of know-how dramatically increases the likelihood of technical assistance being included in the contract. This is confirmed by the value of the Chi-squared test, statistically significant at the 1% level. By contrast, analyzing the relationship between the transfer of patented technology and the provision of technical assistance, the result is the opposite: Table 2c shows that the transfer of patented technology reduces the likelihood of including technical assistance in the contract, with a Chi-squared statistic that is significant at the 1% level.

Thus, technical assistance seems to be associated with the transfer of know-how, but not with that of a patent. This is consistent with the claim that the provision of technical assistance helps to mitigate potential moral hazard problems on the licensor's side, inducing it to transfer the first-best level of technology. However, this is not the only candidate explanation, since the relationship between know-how and technical assistance could also be due by the very non-codifiability of know-how. Indeed, technical assistance, which increases the direct contact between licensor and licensee, is the way the parties have to effectively transfer a kind of technology that is not codifiable. Table 4 will present further evidence on the role of technical assistance in the transfer of tacit knowledge.

4.2. Determinants of the transfer of patents and know-how

Table 3 presents estimated coefficients in a bivariate Probit model where the dependent variables are indicators of the transfer of patented technology and of know-how. This model allows for the error terms in both equations to be correlated. The evidence presented in Table 2a indeed suggests that such correlation should be taken into account. The specification whose coefficients are estimated is the following:

$$V_{1i} = \alpha_0 + \sum_{j=1}^{4} \alpha_j Ind_{j,i} + \alpha_5 Link_i + \alpha_6 Pcs_i + \alpha_7 Duration_i + \alpha_8 Sameind_i + \alpha_9 \ln impts_i + \alpha_{10} \ln sales_i + \varepsilon_{i,1}$$
$$V_{2i} = \beta_0 + \sum_{j=1}^{4} \beta_j Ind_{j,i} + \beta_5 Link_i + \beta_6 Pcs_i + \beta_7 Duration_i + \beta_8 Sameind_i + \beta_9 \ln impts_i + \beta_{10} \ln sales_i + \varepsilon_{i,2} \quad (1)$$

The vector of error terms is distributed $N\left[\begin{pmatrix}0\\0\end{pmatrix},\begin{pmatrix}1 & \rho\\ \rho & 1\end{pmatrix}\right]$, and the observed dichotomous dependent variables are simply,

$$\begin{aligned} Patent_i &= 1(V_{1,i} > 0) \\ KnowHow_i &= 1(V_{2,i} > 0) \end{aligned} \quad (2)$$

i.e. whether patented technology or know-how has been included in the contract.

Columns (i) and (ii) of Table 3 report estimated coefficients of the bivariate probit model using the full sample of contracts, whereas columns (iii) and (iv) report estimated coefficient using only unaffiliated contracts. The reason to consider the unaffiliated subsample isolately is that there might be significant differences between affiliated and unaffiliated transfers. Indeed, the literature typically assumes that moral hazard is less likely to be a problem in affiliated transfers. The regressors include four industry dummies, one for each industrial group except for Agriculture (*Ind* variables). *Link* is a dummy that takes the value 1 if the transfer is affiliated, and zero otherwise. *Duration* is contract duration in years. *SameInd* is a dummy that equals one if both parties to the contract are classified into

the same industry. A transfer between two firms in the same industry is assumed to suffer less from asymmetric information problems. The ln*impts* variable is the logarithm of the percentage of total Spanish imports that came from the licensor's country of origin. It is a measure of asymmetric information both on the licensee and the licensor's side, since a low value of this variable suggests less commercial ties between Spain and the licensor's country, and thus less information about the conditions of the Spanish market. Additionally, a low value also suggests that the licensee has less information about the licensor. Finally, ln*sales* is the logarithm of sales of the Spanish firm in the year prior to the signing of the contract, which had to be reported in the form. This controls for potential differences between large and small firms in the type of technology that they acquire. For instance, if the market value of patents is too high then maybe only large firms, which are assumed to be less cash constrained, will be able to purchase patented technology.

None of the coefficients reported in column (i) of Table 3 is statistically significant, except that on process technology, which is negative. Thus, most patented technology refers to new products rather than improvements in the production of existing products. Neither affiliation nor contract duration seem to affect the probability of patented technology being transferred, suggesting that the legal protection that a patent receives is strong enough to mitigate possible moral hazard problems on both sides.

By contrast, affiliation, process and the indicator of licensor and licensee belonging to the same industry have positive, statistically significant effects in the likelihood of transferring know-how, as seen in column (ii). The affiliation variable is indeed significant at the 1% level, suggesting a strong relationship between affiliation and the transfer of know-how: internal transfers seem to be preferred for the transmission of this type of technology. Duration has no statistically significant effect on the likelihood of transferring know-how. The coefficients on the industry dummies, which are unreported,

are also insignificant in both equations. The logarithm of imports and logarithm of sales variables have statistically insignificant effect on the likelihood of transferring either a patent or know-how.

The fact that there may be significant differences between affiliated and unaffiliated transfers in the type of technology to be transferred suggests the separate analysis of unaffiliated contracts, which is done in columns (iii) and (iv) of Table 3. Using the subsample of unaffiliated transfers, the effects of the different regressors on the likelihood of transferring a patent are similar to those in column (i). Besides the coefficient on process technology, which is negative, highly statistically significant but smaller in absolute value than that in column (i), no coefficient is statistically significant. In particular, duration does not appear to affect the likelihood of a patent being transferred. Concerning the reported estimated coefficients in column (iv), which measures the impact of the regressors on the transfer of know-how, those on process and same industry are positive and statistically significant, as they were in column (ii) and now they are slightly greater in absolute value. The main difference is that now the coefficient on duration is positive and statistically significant at the 1% level, suggesting that unaffiliated contracts that stipulate know-how are significantly longer than those that do not include the transfer of tacit knowledge. This relationship is consistent with duration reducing the licensor and licensee's incentives to behave opportunistically, as discussed in the previous section. Also, the fact that the effect appears only in unaffiliated transfers is consistent with this explanation, since moral hazard problems are more acute in arm's-length transfers. However, there are other explanations consistent with this finding, such as the transfer of tacit knowledge, especially to an unaffiliated party, requiring more time than that of codified knowledge.

Additionally, if the parties belong to the same industry, it is more likely that they agree on the transfer of know-how, with the coefficient on this variable in column (iv) being positive, statistically significant, and greater in absolute value that that reported in column (ii). By its very nature, tacit knowledge requires the licensee to be familiar with the procedures that know-how applies to, in a lesser

degree than in the case of a patent, where a description of it is available. This could explain the positive relationship between the licensor and the licensee belonging to the same industry and the transfer of know-how, as well as the insignificant effect on the transfer of a patent.

4.3. The provision of technical assistance services

Table 4 presents results of regressions that inquire into whether technical assistance is actually bundled together with know-how in order to mitigate moral hazard problems on the licensor's side, as proposed in Arora (1996). For that purpose, it will be analyzed if technical assistance eliminates the effect of duration on the likelihood of transferring patented technology and know-how, within unaffiliated transfers. The evidence suggests that technical assistance actually helps in the transmission of know-how, but has no effect if a patent is to be transferred.

First, column (i) in Table 4 presents estimated marginal effects of a Probit specification where the dependent variable is an indicator of the transfer of a patent, and the regressors are the same as in the case of equation (1), except for the absence of the affiliation variable, since only the unaffiliated subsample will be used, and of industry dummies, because of the low number of observations due to the additional splitting of the sample into contracts which include technical assistance and contracts which do not include it. In column (i) only observations where the contract does not stipulate the provision of technical assistance are used, and no effect is statistically significant, except for that of the technology being of a process type. On the other hand, column (ii) uses observations where the technical assistance services are provided by the licensor. In this case, duration has a positive marginal effect, and becomes statistically significant at the 10% level. If moral hazard on the licensor's side was a major factor driving the likelihood of patented technology being transferred and technical assistance helps mitigating this problem, then the effect of duration should have been positive if no technical assistance services are provided, and null if technical assistance is provided.

Columns (iii) and (iv) do the same exercise but now the dependent variable is, in both cases, an indicator of the transmission of know-how. Now the difference between the estimated marginal effects of duration in columns (iii) and (iv) provides additional evidence consistent with technical assistance helping to mitigate moral hazard problems on the licensor's side. If no technical assistance is provided, the effect of duration is relatively large, increasing the likelihood of know-how being transferred by 7.7% per year of duration of the contract, and statistically significant at the 1% level. By contrast, in the subsample of unaffiliated transfers where technical assistance is provided, the effect of duration is much smaller in absolute value, and loses its statistical significance. Thus, in contracts that stipulate the provision of technical assistance, contract duration is less relevant in determining the likelihood of signing the contract, suggesting that the provision of technical assistance is a partial solution to moral hazard on the licensor's side. It is interesting to stress the asymmetry of this result comparing transfers of codified technology with tacit knowledge: technical assistance only helps in the case of tacit knowledge, which again suggests that moral hazard problems on the licensor's side indeed affect the likelihood of signing the contract.

Additionally, the transmission of technical assistance also makes the effect of the same industry variable less important, although it remains positive and statistically significant. An interpretation of this result is that technical assistance substitutes for lack of knowledge about the usual procedure in a different industry. The effect of the logarithm of imports variable is positive, statistically significant, and it is not influenced by the transmission of technical assistance: know-how tends to be acquired from countries with closer commercial ties with Spain regardless to the efforts made by the parties to reduce moral hazard on the licensor's side. This again is consistent with asymmetric information on variables other than technology characteristics worsening moral hazard problems on both sides.

Finally, the provision of technical assistance dramatically changes the effect of the licensee's size, switching from it being positive and statistically significant at the 5% level to negative and

statistically significant at the 1% level. A candidate explanation is that when no technical assistance is provided, mostly larger firms acquire tacit knowledge because they can more easily bear the loss from possible moral hazard on the licensor's side, and thus, the likelihood of the contract actually being signed is smaller if the licensee is of a smaller size. On the other hand, if technical assistance is provided, then there is less room for opportunistic behavior on the licensor's side, and thus, the true distribution of licensees' sizes appears, with smaller firms more likely acquiring tacit knowledge. An alternative explanation is that small firms lack the resources to maintain a permanent technical staff, making them more dependent on technical assistance provided by the licensor.

5. Conclusions

This paper analyzes the determinants of the transmission of patented and of tacit technology, with an emphasis on the effect of contract duration and on the role of the inclusion of technical assistance. With this purpose, a sample of 165 contracts for the acquisition of technology by Spanish firms from foreign sources in 1991 is analyzed empirically.

The analysis of the sample presents evidence of the positive effect of contract duration on the probability of transferring tacit knowledge in unaffiliated transactions. By contrast, duration has no effect if patented knowledge is to be transferred, regardless of the linkages between licensor and licensee. An explanation for the difference between the two effects could be the legal protection that a patent receives, which is absent if tacit knowledge is to be transferred. This constitutes a potential source of moral hazard problems on the licensee's side. Additionally, the fact that tacit knowledge is uncodified may be an additional source of moral hazard problems on the licensor's side. If the parties sign a long-term contract, then moral hazard problems are less acute because the opportunity cost of opportunistic behavior increases. Since the legal protection and codification of a patent reduce the temptation to cheat, duration has no effect in this type of transfers, but the transfer of know-how,

lacking these two features, is sensitive to duration, which changes the parties' incentives to breach the contract.

In addition to the previous argument, the positive effect of contract duration on the likelihood of transferring know-how could also work by means of an increase in the likelihood of the parties actually signing the contract if duration is long. If know-how is to be transferred and the expected duration of the technology is short, then the potential moral hazard problems on both sides may be so acute that the parties are not able to reach a successful agreement. The fact that duration affects the likelihood of observing the transfer of know-how only within unaffiliated transfers suggests that the problems associated with its transmission may be an important determinant in the successful transfer of tacit knowledge.

The paper also investigates whether the parties include the provision of technical assistance as a way to solve moral hazard problems on the licensor's side. Technical assistance can be seen as a commitment by the licensor to provide the licensee with the first-best level of technology, if contracting upon technological characteristics is impossible. The evidence presented in Tables 2 and 4 is consistent with the claim that these services are indeed used by the parties for this purpose: technical assistance is associated with the transfer of know-how, but not of a patent, and the provision of technical assistance services makes the effect of contract duration in the likelihood of transferring know-how be statistically insignificant.

The evidence presented in this paper is, therefore, consistent with opportunistic behavior being an important determinant of international transfers of technology. However, the data that is available prevent this evidence from being fully conclusive, since there could be other explanations for the results in Tables 2 and 3 not based on the interpretation proposed in this paper. However, the results presented in Table 4, indicating the different role of technical assistance depending on the technology

type, constitutes additional evidence in favor of the explanation proposed in this paper. It would be interesting to study whether this result is also found in other similar datasets.

The results obtained in this paper suggest that the legal protection offered by the patent system in Spain in 1991 was sufficient to ensure that two unaffiliated parties interested in transferring ownership or the right to use a patent were not refrained by potential moral hazard problems. By contrast, the transfer of know-how was much more difficult because of its lack of legal protection and its tacitness. Technical assistance services are introduced as a partial solution to this problem, but whenever this service was not provided, the probability of transferring know-how depended on factors such as contract duration, which determined how acute moral hazard problems were to be. Moreover, it was precisely smaller firms the most likely to forgo the possibility of acquiring tacit knowledge.

Finally, the results obtained in this paper should also induce models that analyze contracts for the transfer of technology to explicitly consider its temporal dimension. To the best of my knowledge, all papers in this field consider instantaneous transfers of technology and analyze how moral hazard, asymmetric information, or risk-sharing influence scheduled payments or the inclusion of certain contract clauses. The fact that contracts differ in their durations has been overlooked in the literature, and in my opinion, deserves more attention.

Acknowledgement

I thank the anonymous referee for his helpful comments. Financial support from the Spanish Ministry of Science and Technology (SEC2002-01839) is gratefully acknowledged. All errors are my own.

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Table 1a. Contract and firm characteristics by industry

Industry	Total Obs.	Know-how %	Patented technology %	Technical assistance %	Process technology %
Agriculture (0)	5	40.0	40.0	20.0	0.0
Energy, Minerals, Chemicals (1-2)	41	85.4	29.3	51.2	51.2
Metal Transformation (3)	58	65.5	27.6	56.9	43.1
Other Manufacturing, Construction (4-5)	29	42.3	20.7	24.1	44.8
Services (6-9)	32	40.6	6.3	56.3	78.1
Total	165	61.8	23.0	48.5	50.9

Table 1b. Contract and firm characteristics by industry

Industry	Unaffiliated %	Ownership %	Duration years	Average sales (pta mn)
Agriculture (0)	80.0	0.0	7.6	1260
Energy, Minerals, Chemicals (1-2)	70.7	17.1	4.8	26992
Metal Transformation (3)	69.0	15.5	4.7	23799
Other Manufacturing, Construction (4-5)	58.6	3.4	4.7	6210
Services (6-9)	71.9	3.2	2.7	24208
Total	68.5	10.9	4.4	20897

Table 2a. Transfers of know-how and patented technology

	No patent	Patent	Total
No know-how	42	21	63
Know-how	85	17	102
Total	127	38	165
Pearson Chi-square			6.103
Probability			0.013

Table 2b. Transfers of know-how and technical assistance

	No technical assistance	Technical assistance	Total
No know-how	44	19	63
Know-how	41	61	102
Total	85	80	165
Pearson Chi-square			13.703
Probability			0.000

Table 2c. Transfers of patented technology and technical assistance

	No technical assistance	Technical assistance	Total
No patent	57	70	127
Patent	28	10	38
Total	85	80	165
Pearson Chi-square			9.714
Probability			0.000

Table 3. Bivariate Probit of transfer of patented technology and know-how

	Full sample		Unaffiliated subsample	
	Patent	Know-how	Patent	Know-how
	(i)	(ii)	(iii)	(iv)
Affiliation	0.19	0.763 ***		
	0.254	0.249		
Process	-0.937 ***	0.451 *	-0.651 **	0.581 *
	0.249	0.238	0.357	0.311
Duration	-0.028	0.029	0.004	0.127 ***
	0.034	0.033	0.046	0.046
Same industry	-0.089	0.425 *	-0.014	0.668 **
	0.255	0.245	0.315	0.304
ln(imports)	-0.052	0.079	-0.001	0.132
	0.119	0.107	0.134	0.125
ln(sales)	0.054	-0.066	0.062	-0.037
	0.546	0.051	0.062	0.059
Constant	-0.228	-0.656	-0.393	-2.25 **
	0.8	0.784	0.975	0.964
Log-likelihood		-159.858		-108.161
Sample size		165		113

All regressions include industry dummies.
Standard errors reported below the estimated coefficient.
* indicates statistically significant at the 90% level (two-tailed test).
** indicates statistically significant at the 95% level (two-tailed test).
*** indicates statistically significant at the 99% level (two-tailed test).

Table 4. Technical assistance as a safeguard against opportunistic behavior

	Patented technology		Know-how	
	No technical assistance	Technical assistance	No technical assistance	Technical assistance
	(i)	(ii)	(iii)	(iv)
Process	-0.278 **	-0.031	0.36 **	-0.113
	0.12	0.099	0.141	0.167
Duration	0.001	0.022 *	0.077 ***	0.024
	0.019	0.012	0.027	0.022
Same industry	-0.001	0.038	0.418 ***	0.281 *
	0.126	0.096	0.127	0.165
ln(imports)	-0.007	0.022	0.134 *	0.135 *
	0.056	0.044	0.072	0.067
ln(sales)	0.027	0.022	0.078 **	-0.086 ***
	0.025	0.019	0.035	0.032
Log-likelihood	-32.913	-17.688	-31.631	-23.042
Sample size	61	52	61	52

Standard errors reported below the estimated coefficient.
* indicates statistically significant at the 90% level (two-tailed test).
** indicates statistically significant at the 95% level (two-tailed test).
*** indicates statistically significant at the 99% level (two-tailed test).