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# On the survival of contracts: assessing the stability of technology licensing agreements in the Brazilian seed industry

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## Abstract

The present study focuses on contract duration as defined ex post, meaning that the "survival" of contractual relationships is observed over time. Our empirical study employs hazard rate models with time-varying covariates, using data from technology licensing contracts between seed companies and a governmental R&D organization in Brazil, EMBRAPA. We find evidence that rates of contract termination (1) decrease with the level of quasi-rents available in the relationship; (2) decrease as a function of past satisfactory outcomes; (3) increase with the extent of disturbances affecting the technology's demand; and, other things being equal, (4) increase (rather than decrease) over time. © 2003 Elsevier B.V. All rights reserved.

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## 1. Introduction

Relationships *intended* to continue over time may fail to do so because of a host of factors not anticipated in ex ante contract terms. Changes internal or external to the exchange may make parties unable or willing to meet pre-specified contract terms, including the duration or length of their agreement. As a result, the analysis of how contractual arrangements

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unfold and, in particular, the factors that promote their stability (i.e., low rates of contract termination) becomes a central issue in the study of economic organization. Yet, the empirical analysis of the duration of contractual relationships has usually been based on ex ante terms, with agents pre-specifying the desired length of the transaction as a contractual clause (e.g., Crocker and Masten, 1988; Joskow, 1987).

The present study focuses instead on contract duration as observed ex post, meaning that we are evaluating the "survival" of contractual relationships over time. This shift of focus is important for two main reasons. As discussed above, pre-specified duration may not be equal to *actual* duration when the contractual arrangement fails to meet the necessary conditions for its continuity. Moreover, the continuation of a series of short-term contracts can be seen as an informal (i.e., with duration not specified ex ante), long-term contractual arrangement (Crawford, 1988). For instance, the pre-specified length of the licensing contracts studied here is 1 year; however, our data reveal cases of contracts that lasted more than 10 years. Focusing on ex ante contractual clauses in this case can be misleading because it provides a partial picture of such evolving relationships and fails to address a critical question: what are the factors that promote the stability of contractual agreements beyond pre-specified terms?

To generate testable propositions related to this question, we begin with the basic argument of self-enforcement models (e.g., Klein and Leffler, 1981; Telser, 1980) that parties continue a relationship if the long-term gains from cooperation (namely, the quasi-rents available in a recurring interaction) surpass the short-term gains from defection. We also suppose that the relationship is subject to uncertainty related to both its intrinsic value (for instance, the attractiveness of the products being exchanged) and to parties' trustworthiness (i.e., their propensity to act opportunistically). This implies, in particular, that individuals may learn from past outcomes and decide to continue or sever a relationship accordingly (e.g., Ghosh and Ray, 1996; Rauch and Watson, 2003). Following Williamson (1991), we also hypothesize that external disturbances affecting the value of the exchange undermine contract continuity because the processes of mutual adaptation to changing conditions become difficult. Finally, we outline competing hypotheses about how the likelihood of termination may vary as the relationship unfolds. While evolving norms and routines tend to reduce termination rates as parties continue transacting (e.g., Lindsey et al., 2000; Ring and Van de Ven, 1994), the value of an ongoing relationship may decline over time (possibly due to the obsolescence of the technology being exchanged) and contribute to an increase in the likelihood of termination (e.g., Ongena and Smith, 2001).

We test these hypotheses in the context of the Brazilian seed industry, using data from technology licensing contracts coordinated by a governmental R&D agency, the Brazilian Federal Agricultural Research Organization (EMBRAPA). We find evidence that rates of contract termination (1) decrease with the level of quasi-rents available in the relationship, (2) decrease as a function of past satisfactory outcomes, (3) increase with the extent of disturbances affecting the technology's demand; and, other things being equal, (4) increase (rather than decrease) over time.

Few empirical studies in the literature have dealt with ex post contractual duration, the continuation or termination of ongoing contractual agreements. These studies include Levinthal and Fichman (1988), analyzing the evolution of auditor–client relationships;

Beales and Muris (1995), assessing the causes of termination of franchising contracts; Kogut (1989), Park and Russo (1996) and Olk and Young (1997), evaluating factors influencing the termination of strategic alliances; and Ongena and Smith (2001), studying the duration of bank–client relationships. Like some of the studies cited above (Kogut, 1989; Levinthal and Fichman, 1988; Ongena and Smith, 2001; Park and Russo, 1996), we use survival analysis techniques (Kiefer, 1988; Petersen, 1995) to model contract continuity. However, unlike these studies, we assess not only the conditions that promote contract continuity, but also how these conditions change over time. This is crucial to test some particular propositions (for instance, that satisfactory *past* performance promotes contract continuity) and to control for time-varying, contract-specific effects that may bias the inference of how rates of contract termination change as relationships unfold.<sup>1</sup>

The study is organized in five sections, including this introduction. Section 2 presents the theoretical framework that supports our predictions. Section 3 presents the empirical context of our study. Section 4 describes the data and methods used to test our hypotheses. Section 5 presents the empirical results, and the final section concludes.

## 2. Contract continuity: theory

We are interested in situations where the duration of relationships is not completely specified ex ante. In the simplest case, this would occur if contracts were formally specified to last for one period only, but were expected to be continuously renewed if parties so desired; this is the case of EMBRAPA's contracts, which are empirically examined in this study. In this setting, it is natural to suppose that parties will, in every period, decide to continue their recurring exchange if the future payoff stream from continuation (net of other external opportunities that parties may have) is larger than possible gains from short-term defection, including the immediate termination of the relationship. Self-enforcement models are built upon this simple idea (Klein, 1995; Klein and Leffler, 1981; Telser, 1980).

Long-term gains from continuation are dependent on the level of *quasi-rents* available in the relationship. Several factors contribute to an increase in quasi-rents. First, relationship-specific assets tend to increase the net gains from continuing a relationship not only because they induce costs to switch to alternative partners, but also because they may be associated with superior technology or processes dedicated to the exchange (Williamson, 1985; Levinthal and Fichman, 1988; Anderson and Weitz, 1992). Second, parties can establish exclusivity clauses that limit the entry of alternative firms that might compete for similar products or markets (Anderson and Weitz). For instance, franchisors commonly establish exclusive territories for franchisees, thereby limiting the dissipation of rents due to interfirm competition (Klein, 1995). Third, the existence of multiple contracts between parties increases the stream of quasi-rents in the exchange because past defection on a contractual agreement is likely to be retaliated by the offended party with the termination of

<sup>&</sup>lt;sup>1</sup> Levinthal and Fichman (1988) use time-varying covariates in part of their discussion of the duration of auditor–client relationships, but their main objective is to evaluate how termination rates vary over time rather than the impact of those time-varying covariates on termination per se.

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the whole nexus of relationships instead of with the termination of that single agreement (Kogut, 1989; de Figueiredo and Teece, 1996; Park and Russo, 1996).

Other factors affect the gains that parties may achieve with short-term defection. *Monitoring* limits the range of implicit or explicit agreements on which a party can renege without being detected by the other party or third-party enforcers. With higher monitoring, parties will anticipate that opportunistic behavior will likely be detected, thereby reducing their willingness to defect.<sup>2</sup> In addition, contractual *safeguards* (e.g., incentives or damages applied to certain contractible exchange dimensions) can partially reduce the gains that parties can achieve by reneging on the whole agreement (Baker et al., 1994; Klein, 1996). Thus, by reducing gains from short-term defection and hence enhancing the perceived net gains from cooperation in a recurring exchange, monitoring and contractual safeguards tend to promote contract continuity.<sup>3</sup>

However, rigorously speaking, an agreement is never terminated under the usual assumptions of self-enforcing models (i.e., common knowledge about preferences and possible payoffs). Backward induction implies that parties will anticipate future outcomes and decide to enter a recurring relationship or not at the outset. Furthermore, parties can endogenously increase the level of quasi-rents in the exchange or, through control and incentive mechanisms, limit gains from short-term defection to make the relationship robust to termination.<sup>4</sup> Thus, we assume additionally that the relationship is subject to uncertainty in such a way that, through repeated interaction, parties may learn the value of continuing versus severing the repeated exchange. This type of uncertainty can be manifested in several ways. First, firms may not know for sure the trustworthiness of their exchange partners. Experience thus allows firms to discontinue the exchange with "fly-by-night" players while at the same time to proceed with partners who have not defected in the past (Ghosh and Ray, 1996; Johnson et al., 2002; Kranton, 1996). Second, firms may not know ex ante the intrinsic value of the exchange; for instance, they may not have complete information about the competencies of their partners or the market value of the technology being exchanged. Recurring transactions allow firms to update their beliefs about the value of the relationship, perhaps changing their willingness to continue the exchange (Olk and Young, 1997; Rauch and Watson, 2003). Collectively, these arguments suggest that satisfactory past outcomes will reinforce contract continuity.

<sup>&</sup>lt;sup>2</sup> One might argue that monitoring can *increase* the likelihood of termination by increasing the detection of opportunistic actions. But this argument assumes that parties' decision to defect is exogenous to the process of monitoring. If agents anticipate that higher monitoring will lead to a higher likelihood of detection, they will be less willing to defect in the first place.

<sup>&</sup>lt;sup>3</sup> We suppose that monitoring is imperfect and safeguards are incomplete (i.e., they cannot enforce all possible contract dimensions under all possible contingencies) because otherwise the study of ex post contract continuity would be immaterial: parties could define ex ante the optimal contract duration and all the procedures to cope with premature termination.

<sup>&</sup>lt;sup>4</sup> We thank an anonymous referee for raising this important point. Ramey and Watson (1997) examine this possibility in a setting where the exchange is subject to random shocks but parties observe the realization of these shocks after they decide to continue or terminate the relationship. They show how parties can make the exchange robust to termination by increasing the level of relationship-specific investments. The idea that firms endogenously choose governance attributes so as to maximize performance is discussed in a different setting by Demsetz and Lehn (1985).

Williamson (1991) provides a distinct argument on how uncertainty may affect contract continuity. He maintains that *disturbances* (external shocks that affect the value of relationships) are likely to destabilize recurring agreements since parties may find it difficult to reach mutual consent on the necessary actions to adapt the exchange to changing conditions. For instance, the adjustment of pre-specified price levels when parties are faced with unanticipated market conditions may be problematic due to costly bargaining or to the inability to reach mutually agreed prices. In this example, disturbances may increase with the variance of shocks that affect the demand of the products being exchanged. Thus, following Williamson (1991), we hypothesize that the likelihood of contract termination will be positively affected by the extent of disturbances that can potentially affect the value of the relationship.

Finally, we offer competing hypotheses on how rates of contract termination may vary as the relationship unfolds. On the one hand, repeated interaction promotes the emergence of informal governance mechanisms such as norms, social attachments and trust, which contribute to increased ability to adapt mutually to external changes and reduced willingness to defect (Macneil, 1978; Granovetter, 1985; Gulati, 1995). Moreover, repeated interaction triggers the emergence of shared routines to govern the exchange (Blau, 1964; Levinthal and Fichman, 1988) that are essentially relationship-specific (Williamson, 1985, p. 62) and thus over time increase the level of quasi-rents available in the repeated exchange. Due to these evolving informal processes, other things being equal, termination rates will *decrease* with the (ex post) duration of relationships (Levinthal and Fichman, 1988; Lindsey et al., 2000; Ring and Van de Ven, 1994). On the other hand, the value of a relationship may decline over time. For instance, the technology being exchanged in a licensing agreement may suffer from obsolescence. Also, as the relationship unfolds, one party may be progressively able to expropriate proprietary information or assets and hence replicate the other party's activities internally. This yields an opposite prediction: termination rates will *increase* with the duration of relationships (Ongena and Smith, 2001).

## 3. Empirical setting

Fig. 1 depicts the seed supply chain in Brazil with its main players and transactions. The first player is the R&D company that develops new plant varieties through traditional breeding or biotechnological processes. Both governmental companies (including EMBRAPA, the focus of our empirical analysis) and private enterprises operate at this level. The second



Fig. 1. The seed supply chain.

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agent is the commercial seed company (also called "seed multiplier") whose basic function is to grow ("multiply") genetically improved seeds obtained from R&D companies (T<sub>1</sub>), in order to produce commercial-scale seeds to be sold to growers. The third agent is the grower, who buys seeds as an input for agriculture production (T<sub>2</sub>) or uses saved seeds from former seasons (T<sub>4</sub>), and then sells the output to elevators and processors (T<sub>3</sub>).

The transaction under analysis in this study is  $T_1$ , which represents an exchange between two specialized agents, the first producing superior genetic materials and the second using this technology to produce seeds. In some cases,  $T_1$  is hierarchically governed (some firms are vertically integrated in this stage, accomplishing R&D and marketing their own commercial seeds to growers). In other cases,  $T_1$  is governed through licensing contracts between R&D companies and seed multipliers. This is the case of the licensing program coordinated by EMBRAPA, a governmental R&D organization in Brazil and the source of our data.

In 1987, EMBRAPA decided to launch a licensing program with a group of small seed companies. Most companies did not have their own R&D departments and were focused on the production of genetic materials in the public domain. The licensing contract allowed the companies to enter the market for highly productive corn seeds (referred to as *hybrids*), which was mostly occupied by large companies with their own R&D departments and strong brand names. The program was considered a success, as EMBRAPA's licensees gained about 15 percent of the Brazilian market for hybrid corn seeds in the first years of operation, and other large-scale seed companies started to practice similar licensing procedures.

The basic characteristics of EMBRAPA's contracts were as follows. The length of the agreement was of 1 year only, but it was expected to be automatically extended after each year. Thus, this is an example of a series of short-term contracts that can evolve into long-term relationships; indeed, we have evidence of relationships that lasted more than 10 years. The royalty for each kilogram of seed obtained from EMBRAPA was fixed, defined as 5 percent of each licensee's annual revenues. Contractual safeguards were fairly standardized across licensees, allowing EMBRAPA to terminate the contracts if royalties were not properly honored, if sub-licensing was observed, or if non-satisfactory technical standards were detected. No exclusive territories were defined, thus allowing for regional competition among licensees. Companies produced the seeds under strict technical standards defined by EMBRAPA. Each company was required to have properly trained personnel and equipment for seed processing. Sales were independently carried out by the licensees, who had to bear a large part of marketing costs. Although EMBRAPA's brand name ("BR") should necessarily be stamped on the seed bag, most licensees also attached their individual brand names to the product.

We consider that a contractual relationship is terminated in a given year if at least one of the parties decides not to renew the agreement for that particular year. Anecdotal evidence indicates that contract terminations were induced by both EMBRAPA (justifications include licensee's default, non-satisfactory technical standards, and unauthorized practices such as sub-licensing) and licensees (spontaneous departures, commonly justified by a lack of interest in the hybrid or by difficulty with sales). Unfortunately, we do not have reliable information about which party triggered the termination of each agreement in our data. For this reason, in the following sections we analyze the termination of contracts regardless of who induced it.<sup>5</sup> This is less of a limitation if we consider that contractual arrangements are bilaterally negotiated transactions where continuity depends on exchange attributes and exogenous conditions that are likely to affect both parties. As Macneil (1978, p. 900) puts it, in the analysis of contract termination, "typically it is the ongoing relation rather than the individual that is the more powerful of the two."

## 4. Data and methods

## 4.1. Data

In this study, we use a panel database of contracts involving the licensing of EMBRAPA's corn hybrid BR-201 from 1991 to 1996.<sup>6</sup> Notice, therefore, that our unit of analysis is a particular transaction ( $T_1$  in Fig. 1) observed over time. Overall, we have 140 observations corresponding to 33 licensing contracts. Our goal is to explain variations in the rate of contract termination, which is a function of the *duration* of the contract: the time elapsed, in years, since the beginning of the contractual relationship between EMBRAPA and a given licensee.

## 4.2. Explanatory variables

## 4.2.1. Quasi-rents

Based on the discussion presented in Section 2, we observe three aspects related to the level of quasi-rents in EMBRAPA's contracts. First, licensees who obtain large amounts of seed from EMBRAPA are likely to have a higher level of investment in technical knowledge, infrastructure, and marketing and sale expenses, part of which are dedicated to the relationship with EMBRAPA. These investments are likely to increase with the quantity of seeds involved in the exchange since large production will demand higher effort of training personnel and selling the final product, as well as more complex infrastructure in terms of storage and processing facilities. This argument has also implications from EMBRAPA's point of view, since this company holds specific investments associated with the technology being transferred and its brand name. In addition, EMBRAPA has lower unit costs to manage individual transactions for licensees requesting large quantities, a factor that increases the quasi-rents embodied in such large-scale contracts. Thus, we employ the variable *Quantity*, which measures the quantity (tons) of seeds obtained by the licensee from EMBRAPA in a given year, as our first proxy of the level of quasi-rents in the relationship. Based on the

<sup>&</sup>lt;sup>5</sup> See Beales and Muris (1995) for an analysis of terminations of franchising contracts distinguishing between events triggered by franchisors and by franchisees.

<sup>&</sup>lt;sup>6</sup> The program actually started in 1987, but we have detailed information departing from 1991 only. Also, even though we have information about other hybrids (BR-205 and BR-206), we did not include them in the sample because their licensing contracts have a smaller number of observations (they were introduced later and for a restricted number of companies), and information regarding the existence of these contracts enabled us to evaluate some determinants of the continuity of contracts involving the BR-201 hybrid, by far the most important in terms of sales. Namely, if a company holds licensing contracts for hybrids other than the BR-201, quasi-rents are likely to increase, thus promoting the continuity of the BR-201 licensing agreement.

discussion above, we expect this variable to be negatively related to the rate of contract termination.

Second, relationships involving multiple licensing agreements are likely to have higher quasi-rents than relationships involving a single agreement. If a seed company defects on an agreement, EMBRAPA is likely to retaliate with the termination of the whole nexus of licensing contracts. The argument operates from licensees' standpoint as well: EMBRAPA will be less willing to induce the termination of an agreement if licensees can retaliate by terminating other agreements too. We can examine this issue in our empirical context since there were several hybrids in the licensing program (BR-201, BR-205 and BR-206), and the data show heterogeneity with respect to the number of contracts held by licensees. Although some seed companies licensed BR-201 seeds only, other companies licensed other hybrids (BR-205 and BR-206). We therefore create the dummy variable *Multiple contracts*, which is coded 1 if the licensee has multiple licensing contracts with EMBRAPA and 0 otherwise. Since this variable is another proxy of quasi-rents, we expect this variable to be negatively associated with contract termination.

Finally, given that the contract did not guarantee exclusive territories for licensees (see Section 3), in some regions one could find several seed companies competing fiercely for the same local market. Seed companies tend to face high costs to pursue alternative markets because they usually hold site-specific investments associated in their regional markets (distribution channels, knowledge of clients, commercial structure, and so on). To measure the extent of regional competition, we employ the variable *Competitors*, which represents the number of licensees competing in the same region. A region is defined by the state where the licensee's headquarters are located, plus adjacent states (since they usually sell in states other than their own). Since competition essentially dissipates quasi-rents, this variable should be positively related to contract termination.<sup>7</sup>

#### 4.2.2. Monitoring

The discussion in Section 2 proposes that governance features aimed at reducing gains from short-term defection, such as monitoring and contractual safeguards, should promote contract continuity. Unfortunately, contractual safeguards are fairly standardized in EMBRAPA's program, so we do not expect heterogeneity with this respect between licensees. However, there is substantial variation with respect to a variable that can largely affect the likelihood of monitoring: the distance between licensees and the headquarters of EMBRAPA's unit managing corn seed licensing contracts. The longer the distance, the more difficult it is to monitor agents and curb opportunistic behavior (Brickley and Dark, 1987). Thus, we employ the variable *Distance*, which measures the distance in 1000 km between the city where each licensee is located and the headquarters of EMBRAPA's unit managing corn seed licensing agreements (located in the city of Campinas, in the state of São Paulo). We expect this variable to influence positively the rate of contract termination.

<sup>&</sup>lt;sup>7</sup> This measure implicitly assumes that regions are of the same size. To control for this problem, we employ a control variable representing the overall corn seed sales in each region, which is described later. We thank an anonymous referee for pointing out this problem.

## 4.2.3. Past performance

The discussion in Section 2 also proposes that, in the presence of uncertainty about the value of continuing a relationship, contract continuity can be a response to *past performance*. Two performance aspects are relevant in our empirical context. First, licensees are supposed to master technological knowledge regarding the production of seeds, in particular agronomic techniques to increase yield (production per area). Second, licensees should also show satisfactory commercial capabilities and effort to contact clients (growers), offer support services, carry out advertising, and deal with distribution channels. Low levels of performance with respect to those dimensions should indicate that licensees either do not have satisfactory capabilities to perform the agreement or are not willing to exert sufficient effort, thereby inducing EMBRAPA to terminate the contract. On the other hand, from licensees' point of view, low performance levels can trigger their exit from the relationship if they interpret that the technology is not promising, provided they have devoted sufficient effort to produce and sell the seeds.

We measure past commercial performance with the variable *Sales efficiency*, which represents the proportion of the licensee's sales (tons) in a given year over the total BR-201 seed produced in this particular year.<sup>8</sup> We measure past technical performance, in turn, with the variable *Productivity*, which represents the licensee's productivity or agricultural yield expressed as the total amount of final seeds produced or "multiplied" (tons) for each kilogram of seeds obtained from EMBRAPA. Based on the discussion above, we expect these two variables to be negatively related to contract termination.

## 4.2.4. Disturbances

We assess the role of disturbances affecting the stability of EMBRAPA's contracts in two ways. First, given the pronounced variation in climatic and soil conditions in Brazil, licensees located in certain regions where the seed is not well-adapted genetically are faced with external factors (e.g., climatic and soil conditions) that may cause large variations in the technical performance of the seed. By contrast, in regions where the seed is well-adapted, the performance of the seed will be relatively more influenced by its genetic content.<sup>9</sup> Second, regions vary with respect to the volatility of the local demand for corn seeds, which affects the market potential of EMBRAPA's products. Substantial variation in technical and demand conditions may require continuous renegotiation of contract terms. However, since contract terms were rigid in EMBRAPA's program (e.g., the level of royalties), such adjustments were not possible, thus straining ongoing agreements subject to external variability.

We therefore employ two variables to measure the extent of disturbances. The variable *Adaptation*, a proxy for technical sources of disturbances, corresponds to the perceived level of genetic adaptation of the BR-201 hybrid to the local conditions of each licensee, based on a scale from 1 to 3. The larger this variable, the higher the adaptation of the seed and therefore the lower the expected impact of environmental variability on its performance. We gathered

<sup>&</sup>lt;sup>8</sup> Since in some cases the licensees do not sell the whole amount of seed obtained from EMBRAPA, there are carry-over inventories for the next year. As a result, in a given year licensees can sell more seeds than they obtained from EMBRAPA in this particular year (the variable can thus be higher than 100%). Unfortunately, we do not have information on inventories to adjust the measure.

<sup>&</sup>lt;sup>9</sup> This is not only a function of the distance between licensees and EMBRAPA since there are distant regions for which the seed is well-adapted.

this information from EMBRAPA's technical experts. The variable *Demand variability*, in turn, measures demand-driven sources of disturbances: it corresponds to the standard deviation of the annual growth of overall corn seed sales in the region where the licensee is located, considering the 5 years preceding the year of observation.<sup>10</sup> The computation of sales growth employs the continuous form  $\ln(\text{Regional sales}_t/\text{Regional sales}_{t-1})$ , where Regional sales, measures aggregated sales of corn seeds in each region (including sales from companies not in EMBRAPA's program), in 1000 t. The demarcation of regions is made in the same way as in the case of the variable *Competitors*. We expect *Adaptation* and *Demand variability* to be negatively and positively associated with contract termination, respectively.

## 4.2.5. Control variables

We also employ the following control variables. *Regional sales*, defined above, indicates the level of corn seed sales in each region (1000 t). This variable is included to control for the differing sizes and demand conditions of the regions under analysis, which may affect the incidence of contract termination. Y92, Y93, ..., Y96 are year-specific dummy variables that control for time-effects such as systemic market conditions, or some "maturation" of the licensing program over time.

## 4.3. Survival analysis

We want to model a situation in which contracts are at risk of being either terminated or continued in a given moment. A simple qualitative dependent variable model (such as probit or logit), which can predict the probability of termination according to exogenous variables, would be able to model causes of termination, but not temporal influences that might be important. If we include contract duration as an exogenous variable to explain termination, we would be using what we want to predict as a predictor, which is unreasonable (Petersen, 1995, pp. 455-456). In this sense, survival analysis using hazard rate functions seems to be more appropriate for the present problem. In a continuous time specification, a hazard rate function h(t) measures the rate at which a contract will be terminated at a given date t conditional on the fact that the contract "survived" up to this date. Time (in our case, years) since the beginning of the contractual relationship with EMBRAPA defines the duration (t) of a given licensee's contract. In the proportional hazards specification, the hazard function h(t) is decomposed in two parts, as follows (see e.g., Allison, 1984; Kiefer, 1988): where  $h_0(t)$  is a duration-dependent component (the "baseline" hazard function), and c(b, x) is a function that does not depend on the duration t, being specified by a vector of exogenous covariates x and coefficients b. We consider an exponential specification for this function:  $c(\cdot) = \exp(bx)$ . The proportional hazards specification assumes that the ratio of hazard rates for two observations with distinct covariate values is constant.

<sup>&</sup>lt;sup>10</sup> This information was obtained from the Brazilian Association of Seed Producers (ABRASEM). Since we only have information about regional sales beginning in 1987, for observations corresponding to years 1991 and 1992 we used information from the previous 3 and 4 years, respectively, to compute *Demand variability*.

In the *Cox proportional hazards* formulation, the model is semi-parametric in the sense that the functional form of the baseline hazard function is left unspecified; the estimation is carried out through partial likelihood. The advantage of the Cox model is that it allows us to assess factors that influence contract termination without having to specify the baseline hazard function. However, this also constitutes a disadvantage of the model, since we cannot use it to test the effect of (ex post) duration on the rate of contract termination, as specified by the competing hypotheses presented in Section 2. For this reason, we run additional proportional hazard regressions using a parametric form for the baseline hazard, namely the *Weibull* specification:  $h_0(t) = at^{a-1}$ . The Weibull parameterization implies that the baseline hazard function is monotonically decreasing if a < 1, constant if a = 1, and monotonically increasing if a > 1. Thus, by assessing parameter a we can test the competing predictions on how duration may affect the termination rate of contracts. If termination rates increase with the duration of contracts, then a > 1: the hazard function is said to exhibit *positive* duration dependence.

Contracts that were not terminated until the last year of analysis (1996) constitute "right-censored" observations and are properly controlled in the estimation process.<sup>11</sup> Given the nature of the data, the vector of covariates *x* is defined both temporally (time-series for a single licensee) and in cross-section (observations of several licensees at a given date). Thus, except for *Adaptability* and *Distance*, all covariates are time-varying, being observed every year. This is an important distinction of our empirical analysis that allows us both to assess how changing conditions affect the termination of contractual agreements and to control for time-varying, licensee-specific factors that may affect the inference of how termination rates vary over time. All variables are measured in the year prior to the observation of construction. This reduces the problem of ambiguous causality between regressors and duration (Petersen, 1995). Since it is likely that successive observations corresponding to a particular licensee are not independent, we estimate robust standard errors by clustering on each licensee (Lin and Wei, 1989).<sup>12</sup>

## 5. Results and discussion

Table 1 reports descriptive statistics and correlations of the variables used in this study. An inspection of the correlation matrix reveals no possible problems of multicollinearity. Table 2 reports a preliminary, non-parametric analysis of the duration of the contracts under analysis and of the associated hazard rates. It seems that the rate of termination is higher for

<sup>&</sup>lt;sup>11</sup> Even though the licensing program started in 1987 and we only have detailed information from 1991, we do know the first year a given company joined the program. Thus, "left-censoring" (unknown entry dates) is not an issue here.

<sup>&</sup>lt;sup>12</sup> We note that hazard functions assume that termination dates are continuous. In the present cases, termination dates are discrete, since contract termination is observed each year. However, if there is a small number of "ties" (in our case, multiple terminations within the same time interval), then discrete-time and continuous-time models will yield similar estimates (Petersen, 1995). Examining the pattern of terminations in our database (see Table 2), we conclude that the number of ties can be considered small (see e.g., Allison, 1984, p. 42). In the estimation process, we employed the Breslow method to adjust for ties.

De	Descriptive statistics and correlation matrix ( $N = 140$ )																
	Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Length	5.043	1.978	1													
2	Quantity	5.507	5.000	0.467*	1												
3	Multiple contracts	0.629	0.485	0.452*	0.057	1											
4	Competitors	15.350	5.138	-0.130	-0.035	-0.124	1										
5	Distance	0.649	0.306	$0.186^{*}$	0.208*	0.044	$-0.445^{*}$	1									
6	Adaptation	2.407	0.709	0.106	0.123	0.004	0.662*	0.185*	1								
7	Demand variability	0.114	0.052	0.142	-0.090	0.085	$-0.220^{*}$	$-0.169^{*}$	$-0.327^{*}$	1							
8	Sales efficiency	0.913	0.190	-0.131	0.058	-0.131	-0.148	0.040	-0.126	$-0.249^{*}$	1						
9	Productivity	2.272	0.899	0.126	0.063	0.128	0.141	0.019	0.254*	0.077	0.002	1					
10	Regional sales	58.777	18.268	-0.048	-0.100	-0.063	0.198*	$-0.642^{*}$	$-0.251^{*}$	0.501*	-0.147	0.078	1				
11	Y92	0.171	0.378	$-0.270^{*}$	0.011	$-0.592^{*}$	0.039	-0.027	0.006	-0.029	0.163	0.080	0.099	1			
12	Y93	0.171	0.378	-0.058	0.014	0.114	0.124	-0.002	0.033	-0.143	-0.043	-0.084	0.048	$-0.207^{*}$	1		
13	Y94	0.179	0.384	-0.001	0.003	0.320*	-0.163	-0.007	-0.058	$-0.285^{*}$	0.240*	0.099	-0.023	$-0.212^{*}$	$-0.212^{*}$	1	
14	Y95	0.171	0.378	0.221*	-0.032	0.350*	-0.057	0.006	-0.021	-0.052	0.124	0.015	$-0.272^{*}$	$-0.207^{*}$	$-0.207^{*}$	$-0.212^{*}$	1
15	Y96	0.164	0.372	0.421*	0.023	0.301*	-0.064	0.006	-0.010	0.606*	-0.491*	0.073	0.223*	$-0.202^{*}$	$-0.202^{*}$	$-0.207^{*}$	$-0.202^{*}$

\* P < 0.05.

Table 1

Duration interval (years)	Number of contracts within interval	Number of contract terminations	Hazard rate		
1–2	33	1	0.031		
2–3	32	0	0.000		
3–4	31	3	0.102		
4–5	28	1	0.039		
5-6	24	0	0.000		
6–7	23	4	0.211		
7-8	15	2	0.160		
8–9	10	0	0.000		
9–10	9	1	0.222		

Table 2Contract duration: non-parametric analysis

contracts with longer duration (thus suggesting a situation of positive duration dependence) but there is substantial variation across different intervals. The consideration of time-varying factors inducing variation in the rate of termination is therefore needed.

Table 3 shows the results of the proportional hazard estimation under distinct model specifications. Models (1) and (2) correspond to the Cox formulation, which assumes no functional form for the baseline hazard. The first model includes control variables only,

## Table 3

Contract duration: estimates of proportional hazards models<sup>a</sup>

	Specification of the baseline hazard function							
	Cox (unspecified)		Weibull (parameter a)	)				
	1	2	3	4				
Quantity	_	-0.133 (0.131)	_	-0.329 (0.155)**				
Multiple contracts	_	-5.363 (1.675)*	_	-1.104 (0.895)				
Competitors	_	0.647 (0.249)*	_	0.509 (0.252)**				
Distance	-	0.959 (1.638)	-	0.392 (1.737)				
Sales efficiency	_	-13.572 (3.674)*	-	-2.804 (1.893)***				
Productivity	-	0.409 (0.345)	-	0.127 (0.409)				
Adaptation	_	-1.383 (0.836)**	-	-0.982 (1.323)				
Demand variability	-	80.875 (39.894)**	-	72.059 (21.422)*				
Regional sales	0.021 (0.017)	-0.056 (0.053)	0.023 (0.015)	-0.058 (0.035)***				
Y92	-1.084(1.002)	-0.283 (2.349)	-1.263 (1.235)	0.302 (1.156)				
Y93	-1.550 (1.022)	1.620 (2.689)	-0.503 (0.968)	0.832 (1.525)				
Y94	-46.640 (1.821)*	-20.327 (2.761)*	-16.892 (0.941)*	-15.577 (2.032)*				
Y95	-1.602 (1.691)	2.545 (2.038)	-1.674 (1.811)	-2.314 (3.167)				
Y96	-1.880 (1.632)	-7.121 (2.280)*	-1.315 (1.414)	-8.37 (2.822)*				
а	_	_	2.562 (1.234)**	5.783 (3.199)*				
Constant	-	-	-6.300 (2.344)*	-17.848 (6.243)*				
Log-likelihood	-26.022	-16.119	-15.435	-5.929				
$\chi^2$ (Wald test)	2198.06*	1240.07*	3352.01*	3636.90*				

<sup>a</sup> N = 140 and robust standard errors are in parenthesis.

\*\*\* P < 0.10 (one-tailed tests for hypothesized effects).

<sup>\*</sup> P < 0.01.

<sup>\*\*</sup> P < 0.05.

whereas the second model includes all explanatory variables. A likelihood ratio test shows that the inclusion of variables related to hypothesized effects significantly improves model fit (P < 0.05). The other models, (3) and (4), correspond to the Weibull parameterization. As in the case of the Cox model, the inclusion of variables related to hypothesized effects significantly improves the explanatory power of the Weibull model (P < 0.05). Table 3 reports estimates corresponding to the vector of coefficients *b*. A useful way to assess the economic impact of each variable is to consider the coefficients in the relative hazard form, exp(b); this gives the factor by which the termination rate is multiplied due to an increase in one unit of the corresponding covariate.

The data reveal effects consistent with the hypothesis that quasi-rents decrease the rate of contract termination. Although *Quantity* is insignificant in the Cox model, it becomes significant when the Weibull specification is employed. Based on the estimate from model (4), an additional ton of seeds transferred from licensees to EMBRAPA decreases the hazard rate by around 28 percent. The coefficient of *Multiple contracts* shows significance in the Cox model, even though it is insignificant in the Weibull model. According to the estimate from model (2), the existence of multiple contracts is expected to decrease the hazard rate by 99.5 percent. The coefficient of *Competitors*, in turn, is significant in both the Cox and Weibull models. According to the estimates from models (2) and (4), an additional competitor in the region of a particular licensee is expected to increase the hazard rate by 91 and 61 percent, respectively. Although the effect of the covariates changes according to distinct model specifications, the results provide support for the claim that the level of quasi-rents is an important determinant of ex post contract duration, especially with regard to the effect of regional competition.

Although having the predicted sign, the coefficient of *Distance* is insignificant in all models. Thus, our data do not support the prediction that the distance between licensees and EMBRAPA's headquarters will positively affect contract termination due to an increase in monitoring difficulty.

As for the covariates related to past performance, only the effect of commercial performance (*Sales efficiency*) shows statistical significance, and its effect is more pronounced in the Cox model than in the Weibull model. Taking the estimates from models (2) and (4), an increase in one percentage point of sales efficiency (i.e., the proportion of seeds sold based on the total quantity produced) decreases the termination rate of contracts by 13 and 3 percent, respectively. The coefficient of the variable related to technical performance (*Productivity*) is insignificant in all models. Maybe *Productivity* is strongly influenced by factors out of licensees' control (such as adverse climatic conditions), being too noisy a variable to provide reliable information about their effort or competencies.

There is also evidence of the impact of technical and demand-driven sources of disturbances on the duration of contracts. Although *Adaptation* has the expected sign in all models, it is only significant in the Cox model (2): the estimated coefficient indicates that a unit increase in the index of genetic adaptation of the seed to the licensee's local conditions decreases the hazard rate by 75 percent. *Demand variability*, in turn, is significant in all models. Very small increases in the standard deviation of past sales growth seem to have a very large impact on the rate of contract termination. Thus, especially with respect to demand volatility, our data lend support for Williamson's (1991) proposition that external disturbances tend to destabilize contractual agreements.

The Weibull parameter a is central to test predictions related to shape of the hazard function. Both models (3) and (4) reveal that parameter a is significant, but it indicates *positive*, rather than negative, duration dependence: the longer the ex post duration, the higher the rate at which contracts are terminated. Furthermore, the effect is very pronounced: for instance, according to model (4), an increase in the duration from 5 to 6 years is expected to increase the termination rate by around 139 percent. However, since the Weibull specification accommodates only monotonic patterns of the hazard rate, it can provide spurious results when the rate is non-monotonic. For instance, in their analysis of the duration of auditor-client relationships, Levinthal and Fichman (1988) found that the hazard rate increases in the first years of the relationship, and then decreases. The authors employed a log-normal hazard model that accommodates such non-monotonic pattern. To verify this possibility, we fitted a log-normal model to our data using all control variables (results not reported here). Since the log-normal and Weibull models are nested, being particular forms of the generalized gamma model, we can statistically test their relative fit (see e.g., Kalbfeisch and Prentice, 1980). The log-likelihood of the log-normal model (-7.144) is actually lower than the log-likelihood of the Weibull model (4) reported in Table 3, even though the difference is not significant as evidenced by a likelihood ratio test.

There are two possible explanations for the positive duration dependence of hazard rates in our context. First, since new genetic materials are introduced every year by alternative R&D companies, current materials offered by a particular firm such as EMBRAPA can quickly become obsolete years after their introduction. Thus, every year licensees face the choice of focusing on seeds supplied by current partners or pursuing alternative (and perhaps superior) seeds through partnerships with other R&D companies. Second, licensees may become increasingly able to expropriate EMBRAPA's technology and develop their own genetically improved seeds as they gain experience with the hybrids.<sup>13</sup> This suggests that the value of the licensing agreements analyzed in this study tended to decline over time, progressively contributing to an escalation of termination rates.

## 6. Conclusions

This study contributes to the literature on long-term contracting especially because it carefully analyzes contract duration on an ex post basis, thus moving beyond the usual focus on duration or length as a contractual clause defined ex ante. On the one hand, transactions that are defined ex ante as short-term relationships (e.g., contract clauses specifying a short

<sup>&</sup>lt;sup>13</sup> Since seeds carry most of the relevant technology and can be easily multiplied without payment of royalties, enforcement of intellectual property is problematic in the seed industry (e.g., Perrin et al., 1983; Zylbersztajn and Silva, 1992). Until 1998, Brazil had not approved a plant breeders' rights legislation, which is supposed to protect the intellectual property of R&D companies. A factor that certainly reduced licensees' ability to expropriate EMRBAPA's corn seeds is that they are hybrids and, as such, no seeds harvested from one generation will carry their original genetic potential in future generations. By contrast, non-hybrid seeds (also known as plant varieties), such as soybeans, maintain the same genetic characteristics in future generations. However, licensees could possibly create new materials by gradually fertilizing the plants generated from EMBRAPA's seeds into other plants or selecting materials exhibiting similar performance features over several seasons. The difficulty of enforcing intellectual property rights in the seed industry, even in the presence of appropriate legislation, has led some firms to adopt tighter controls over the supply chain and even vertically integrate (e.g., Kalaitzandonakes and Bjornson, 1997).

contract length) can lengthen when evaluated ex post, as in the case of the licensing contracts studied in this paper. On the other hand, transactions that are defined ex ante as long-term relationships can prematurely terminate due to internal or external factors causing instability. It follows that an analysis of the factors that promote or undermine the ex post duration of transactions is crucial to assess the actual performance of contractual arrangements beyond pre-specified clauses. Within this perspective, our paper helps to unpack processes inducing the stability of commercial relationships over time, an issue that has received little attention in organizational economics (Williamson, 1993, p. 94).

Our data reveal several important factors affecting the continuity of technology licensing contracts. We find that the termination rate of contracts decreases with the level of quasi-rents available in the relationship, in particular with respect to the level of local competition faced by licensees. Our data also show that termination rates decrease as a function of past satisfactory outcomes, thus suggesting that parties learn the value of continuing ongoing contracts as the relationship unfolds. In addition, we find that termination rates increase with the variability of licensee's regional markets, suggesting that recurring agreements are sensitive to external disturbances. Finally, in our context, contractual relationships become increasingly more likely to be severed as they unfold. Apparently, the value of the licensing contracts analyzed in this study decreases over time, possibly because of technology obsolescence, or because licensees become increasingly able to expropriate the technology being exchanged.

Our study has important limitations. The generalization of the findings are limited due to the specific nature of the problem under analysis and the limited sample, but the results leave room for similar studies in other industries and contexts. In addition, since we focus on a single industry, a single product and a single licensor, our data lack heterogeneity with respect to some exchange attributes, governance mechanisms, and industry effects. For instance, we cannot assess the effect of distinct contractual safeguards on ex post duration. Furthermore, we are not able to discern the causes of positive duration dependence (increasing termination rates) in our empirical context. Although this finding is consistent with previous research (e.g., Kogut, 1989; Ongena and Smith, 2001), there is evidence that relationships exhibit negative duration dependence and even follow non-monotonic patterns in other contexts (e.g., Levinthal and Fichman, 1988). Future studies should attempt to observe diverse types of exchanges, arrangements, and industries in order to reconcile these findings and evaluate a broader range of factors that may affect contract continuity.

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