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Why do royalties reign in the market for technology?

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Abstract

It is unclear why royalties are the dominant mode of payment in contracts over the trade of pre-commercial technology. We evaluate possible reasons for including royalties in a contract using a dataset of 645 contracts. This data shows systematic differences between the behaviour of university TTOs and private sellers even after controlling for attributes of the technology and trading partner. There is evidence that transaction costs influence the mode of payment but the presence of royalties is associated with more, not less, negotiation breakdown.

Keywords: Contract design; market for technology

JEL: L24, D86, 032

1. Introduction

Transactions in early-stage technology are critical junctures in translation of basic research, not only from the public research sector to industry, but also within industry itself (Arora *et al.* 2004, 2010, Chesbrough 2006, Savva and Taneri 2014, Reslinski and Wu 2016). This vertical separation of the product development process has many benefits. It can facilitate technical specialization, spread risk and enable faster development times (Lamoreaux and Sokoloff 2001, Piachaud 2002, Gans and Stern 2010, Bianchi *et al.* 2011, Thomson and Webster 2012). However, transacting an uncertain intangible product requires sensitive legal treatment. Negotiated contracts blend upfront and contingent payments, such as royalties and milestone payments, in order to manage the range of trading hazards which arise. The stakes are high - an improperly designed contract can diminish overall project value; reduce the benefits realized by the licensor; or, result in expensive legal disputes (Savva and Taneri 2014, Reslinski and Wu 2016).

From an economic viewpoint, the widespread use of royalties is one of the more perplexing regularities in technology transfer. Among contracts governing technology transfer from US universities, royalties are the most common form of contingent payment and generate the majority of licencing revenue (Jensen and Thursby 2001, Reslinski and Wu 2016). In our survey of early-stage technology transactions, we find that six in ten of contracts included royalty payments. Despite their popularity in the field, the drawbacks of royalties are well understood by contract theorists. Royalties on sales distort output decisions by driving a wedge between marginal revenue and marginal cost. This reduces sales and therefore project value, compared with other payment modes. Royalties can be costly to monitor and difficult to design where the future use of the technology and its contribution to product value is unknown (Dechenaux *et al.* 2011, Savva and Taneri 2014, Reslinski and Wu 2016).

Benefits which apparently favour royalties – shifting risk back to the seller, incentivising ongoing inventor participation, and signalling quality – can also be achieved using alternative contingent payment modes such as milestone or equity payments (Jensen and Thursby 2001, Savva and Taneri 2014). Compounding this puzzle, evidence suggests that, among university technology transfer in the U.S., the total value received by universities via equity deals is higher than royalty revenues (Bray and Lee 2000) and that businesses in-licencing university technology consider milestone payments a superior strategy to incentivise ongoing inventor participation (Dechenaux *et al.* 2011).

Why then are royalties so prevalent among contracts for early-stage technology? To date, the literature provides three possibilities, though none have been conclusively validated empirically. The first is that where buyers are large or have a diversified profit stream, the value of equity is inadequately linked to project success to meaningfully shift risk or motivate ongoing inventor participation (in this case the seller 'gets paid' irrespective of project outcome). The second argument, attributable to Savva and Taneri (2014), is that royalties can be used as a screening mechanism, where buyers are better informed about the market value of the technology. The third conjecture that royalties are prevalent among university technology transfer offices (TTOs) because their decision makers lack experience or institutional capability (Bray and Lee 2000, Feldman *et al.* 2002).

In this paper we shed new light on what underpins the widespread use of royalties using new data covering a random sample of 645 contracts drawn up for the trade of pre-commercial technologies. Our data, collected via a systematic survey of the market for pre-commercial technology in Australia, cover all forms of technology transfer including licencing, sale and spin-offs. To our knowledge, this is the first empirical study reporting systematic evidence on contract design for trades in *pre-commercial* technology both from TTOs and between for-profit firms. Our data allow us to directly examine the extent to which the dominance of royalties is unique to university TTOs and, if so, whether it reflects preferences of the institutions or if it can be explained by the attributes of the traded technologies.

We find that the data do not support the signalling hypothesis of Savva and Taneri (2014), nor the use of this payment mode to shape post-contract behaviour (ongoing inventor participation). We find some evidence that transaction costs are important in determining the mode of payment. Overall, the data reveal systematic differences between the behaviour of university TTOs and private sellers even after controlling for attributes of the technology and trading partner. Nonetheless, we find that the presence of royalties on the offered contract is associated with more, not less, negotiation breakdown.

2. Framework and hypothesis development

Traditionally, it has been common among economists, classically using principal-agent models, to reduce the problem of payment choice (contract design) to a binary decision between a fixed upfront fee and profit share (Gallini and Wright 1990, Crama *et al.* 2008, Dechenaux *et al.* 2011).[1] In most instances, these studies also focus on a single *function* performed by contingent payments (risk sharing or signalling or transaction costs) regardless of the specific instrument. The parsimony of these models serves to elucidate each contracting concern, but comes at the cost of providing real-world guidance to practitioners. In practice, negotiating agents routinely include a mix of contingent modes to simultaneously grapple with multiple hazards.

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[1] A rare exception is Savva and Tanari (2014).

We refer to milestone payments, royalties and equity as contingent payments, since they are contingent on technical or market success. A milestone payment is a fixed amount to be paid if a defined technical feasibility is demonstrated. Royalties are dues sellers receive on future sales. This is most commonly defined as ad valorem on total value of sales of products embodying the technology, but is sometimes defined as a dollar amount per unit sold. An equity deal involves the seller receiving a (minority) share of the buyer's company thereby giving the seller a claim on future profits. In some cases, the equity is from a spin-off company which has been created to commercialise the technology.

In this section, we review how royalties and the alternative contingent payment modes (equity and milestone payments) address key trading hazards, with a view to identifying conditions that give royalties an unambiguous advantage. We begin with a critical overview of the main functions of key contract features identified in the management and economic literature and subsequently consider empirically how contracts drawn in the Australian market conform to these predictions.

Allocation of risk

The development of pre-commercial technology involves technical risk (will it work?) and market risk (will it sell?). The first-order risk-allocation function of all contingent payments – royalties, equity and milestones – is to shift risk from the buyer back to the seller, relative to upfront payments. In this way, contingent payment modes can generate joint surplus by allocating risk in a manner that reduces the joint cost of bearing risk.

To identify the role of risk in determining contract design, it is necessary to make assumptions about the risk preferences of various trading parties (Allen and Lueck 1995, Ackerberg and Botticini 2002). Although risk preferences are not directly observable, it is generally held that the cost of bearing risk is lower for large, diversified firms. Similarly, the size and asset base of universities and public research organisations insulates their technology transfer offices from downside risk. TTOs are likely to have an appetite for exposure to upside risk as the reputational cost to a TTO employee who fails to capture a substantial share of a major blockbuster technology is likely to exceed the risk of failing to sign a deal at all. After all, most university invention disclosures are never out-licenced or sold (Feldman *et al.* 2002).

Milestone payments typically act to insure the buyer against a known (and codifiable) technical early-stage risks, such as failed clinical trial results. Milestones cap seller's exposure to upside risk; i.e., large windfall payments in the event of unforeseen value creation. By comparison, royalties and equity transfer both upside and downside technical and market risks to the seller. That is, the seller assumes some risk associated with project failure, but also stands to gain a potentially large windfall in the case of an unexpectedly highly successful product (Bray and Lee 2000, Feldman *et al.* 2002).

Royalty payments and equity have been described as potential substitutes in shifting risk (e.g., Savva and Taneri 2014). However, the risk transferred via royalties and equity differs in important ways, especially if a patent is involved. Monetizing royalties requires that products are sold, even if those sales are made at a loss. In contrast, sellers receiving equity still hold something of value if their technology is abandoned or replaced in the buyer's portfolio (Bray and Lee 2000). In this case, a seller can still benefit from early exit via recapitalisation or IPO.[2]

[2] However, relative risk transfer may be idiosyncratic in the case of start-ups based around a single technology. In this case, solvency ultimately depends on market success in the long run. The seller may still receive some compensation via early exit (equity) or early unprofitable sales (royalties). The relative likelihood of achieving

These options mean that equity can provide fewer downside risks to sellers than royalties. Correspondingly, from the buyer perspective, royalties allow the cleanest break, with no further payments to the seller.[3]

The ability equity deals to allow the seller to capture value even if no product is commercialised is particularly important where a patent is involved. Patents often create value for the buying firm even if the technology is not worked into a product because patents can be used to establish freedom-to-operate; to block competing technologies; or to enhance a bundle of rights used for cross-licensing.

In general, royalties have more downside risk to the seller compared with equity, but less downside risk for the buyer. As risk-averse entities, small sellers will prefer all upfront payments and no contingent payments in their contracts, but if placed in a position to choose, we expect that small sellers are most likely to accept equity if there is a patent; and royalties if the technology is late stage.

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either prior to the start-ups ultimate failure depends on technology type and the market readiness of the technology under development inter alia.

[3] Royalties sometime stipulate minimum payments. Equity also introduces risks to the seller associated with dilution.

Hypothesis 1: Where risk management is a dominant consideration in contract design, we expect that:

(a) TTO sellers will prefer royalty payments

(b) Risk averse (small) sellers will avoid royalties (and all contingent payments).

(c) Risk averse (small) sellers will prefer equity if a patent exists.

(d) Risk averse (small) sellers will prefer royalties if the technology is late stage.

Transaction costs

Transaction costs comprise information costs associated with shaping the terms of the sale as well as ongoing relationship costs, which comprise the ongoing monitoring, verification and enforcement of payments (Chueng 1969; Stiglitz 1974; Hallagan 1978; Leffler, Rucker, 1991). Given the inherent uncertainty surrounding a new technology, all payment modes have considerable information costs about the value of the technology. In equity deals the buyer, often a venture capital firm, amass detailed knowledge of the proposal. Though in all cases the buyer must establish the business case, regardless of payment mode. Setting royalties can be particularly problematic for early-stage technology due to difficulties in defining the basis of payment where the exact use of the technology may be poorly defined, or unknown (Dechenaux *et al.* 2011). Practitioners report that royalty rates are often based on cultural norms and 'rules of thumb' – for example, taking a royalty rate of five percent of sales as a starting point of negotiation. Of course, there is little reason to believe this rate is economically optimal and the cost of sub-optimal rate may be large even if it remains unmeasured. Setting royalties can be particularly problematic for early-stage technology due to difficulties in defining the basis of payment where the exact use of the technology may be poorly defined, or unknown (Dechenaux *et al.* 2011).

Whereas valuation costs may be similar, relationship costs differ substantially between royalties and equity. The costs of enforcement and monitoring are low for upfront payments and milestone payments as both rely on (relatively) narrowly defined observable technical outcomes. Ongoing costs of equity and royalties can be considerable. Equity deals invoke well-known monitoring costs associated with ensuring managers do not act to minimise accounting profits, and therefore payments to equity holders (that is, privatised joint project returns). Monitoring and enforcement costs arise in the case of royalties because the seller must be able to observe sales in products embodying the technology (or verify technology substitution). The trail of administrative and record keeping costs on both parties is considered to be especially large for early-stage technology where the exact use of the technology may be poorly defined, or unknown (Dechenaux *et al* 2011). Costs associated with royalties appear less well acknowledged; while audit provisions are routinely included in royalty contracts, they are seldom enforced. On the other hand, where litigation does occur, evidentiary standards for infringement can be very high.[4] It is

Practitioners advise that the accounting costs of royalties are convex in variety and scale; costs increase disproportionally as the number of distinct royalties transacted per firm increases. It follows that large, multi-product multi-technology buyers and sellers are expected to be more sensitive to transaction costs than are their smaller counterparts. Similarly, the costs of managing significant ownership of smaller technology companies can over complicate relationships in large companies.

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[4] In the absence of contractually implied admission, the patent holder in the CSIRO WLAN case was required to reverse engineer the silicon chips to demonstrate that they embodied the technology on which royalties were due – even though they were marketed as adhering to the industry standard which required them to embody the technology. IEEE standard 802.11a embodied the CSIRO WLAN patented technology.

Hypothesis 2: If perceived transaction costs are a dominant consideration in contact design, we expect that:

(a) large buyers and sellers will prefer upfront and milestone payments over royalties and equity.

(b) The preference for royalties will be higher for late-stage technologies

Ongoing seller (inventor) participation

Ongoing intellectual contribution from the inventor is often required for successful development as inventors sometime possess detailed technical knowledge about the technology, much of which is tacit (Jensen and Thursby 2001, Lach and Schankerman 2008). Contracts commonly nominate ongoing seller involvement, which sometimes include specific contracted research inputs.

All contingent payments can provide an incentive for the seller to continue to lend intellectual support for the development of the technology. Where the required input can be codified, milestone payments can provide the sharpest incentive. By contrast, royalties and equity support an incentive for the inventor to continue to invest without specifying inputs or outcomes. Equity deals can be crafted to create very high-powered incentives for inventor participation. It is not uncommon for equity deals to include a requirement that the scientist has 'skin in the game' via contribution of their own personal finances including taking a second mortgage on their family home. Equity given to the seller as shares in a large firm with diversified income streams however, will not strongly tie seller remuneration to project success. In this case, royalties have an advantage over the alternatives where project success also requires non-verifiable (non-contractible) inventor input.

Hypothesis 3: If motivating ongoing inventor participation is an important consideration in contract design, we expect that where inventor participation is indicated in the deal, large buyers prefer royalties over equity.

Incomplete information

By accepting remuneration contingent on project success, a party can signal its confidence in, or superior information about, the project. For example, if sellers are better informed about project value, they can signal confidence by accepting contingent payment in the form of a royalty, milestone or equity.[5] In general, such models predict risk is positively associated with contingent payments. The specific predictions of signalling models depend on assumptions regarding which party has more information. Principal-agent models previously proposed assume variously that: the seller has more information about the technical feasibility (Bhattacharya and Ritter 1983); the seller has more information about the value of the technology (Gallini and Wright 1990); or, that the buyer has more information about the market value of the technology (Savva and Taneri 2014). An *a priori* case can be made for each set of assumptions, but evidence conclusively documenting which form of asymmetry dominates remains lacking.

Signalling can generally be achieved via any form of contingent payment. However, royalties can have a specific utility when *buyers* have more information about the value of a technology. Savva and Taneri (2014) take the case where the sellers wish to package the technology in a spin-off company but cannot distinguish between their high and low value

[5] Much of the early literature examining this kind of signalling via contingent payments does not consider equity, however, to the extent that equity ties remuneration to project success equity deals can often achieve this signalling function (Savva and Taneri 2014).

projects. If they demand a large share of equity in the spin-off, high-value technology will sell, but low-value technology will be unsold, because holding the remaining small share will be inadequate to cover the investment of the buying firm. If the seller demands only a small equity share, both high and low-value technology will find a buyer, but this comes with the opportunity cost that the has only retained less of the high value projects than they could have. Savva and Taneri (2014) suggest that, if high-value technologies are those with highly elastic market demand, then sellers can use royalties as a screening mechanism to identify high-value technologies. In this case, sellers need only offer a choice between being paid with a high equity share or being paid with a combination of a low and a royalty payment. If (as assumed) royalties destroy more value for high-value projects, buyers of high-value projects can be 'forced' to give sellers a high equity share (and no royalty). The seller has successfully retained a high equity share in contracts to buyers of high-value projects and a low equity share in low-value technology – without knowing which one is which *ex ante*.

The key assumption, of course, is that higher value technologies exhibit higher elasticity of demand and this may not hold in practice. Anything with few substitutes will be inelastic. For example, pharmaceutical technology is often very high value and demand for pharmaceuticals is typically highly *inelastic*, yet royalties are commonplace in the case of pharmaceuticals. Technologies that comprise a small part in total product cost will also be inelastic but may be very high value – the *Breeds* electromechanical sensor for automotive airbags is an example. Savva and Taneri's (2014) model also implies that negotiations are more likely to end in contract execution if contracts with royalties are on the table, which we will test empirically.[6]

Hypothesis 4: If royalties are being used to separate high from low value technology, we expect that:

(a) royalties are associated with low-value technology;

(b) contracts which include royalties are more likely to end in contract execution.

3. Data and descriptive statistics

Our analysis is based on an enterprise survey, which yielded complete data on 645 contracts governing the sale of early-stage technology in Australia, between 2009 and 2011.[7] In the survey, a technology transaction is defined as:

> A non-commercial ready technology that is exchanged between organizations for further development. Exclude transactions between parents and subsidiaries. Exclude material transfer agreements.

The survey was administered to people in organisations that acted as intermediaries in technology trading. In order to identify the survey population, 66 semi-structured interviews were undertaken around Australia during 2010. Ultimately, the survey was posted to 1,427 people and a response rate 47.0 per cent was achieved. This high response rate was achieved by the provision of an incentive in the first mail-out (a A$50 gift voucher).[8] In light of the high

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[6] The authors present numerical simulations which indicate that, given the choice between equity only and royalty with equity, negotiation breakdown is be uniquely associated with equity only contracts, and that negotiation breakdown is negatively associated with offering royalties in all cases described.

[7] See Jensen *et al.* (2015) for further details on administration of the survey.

[8] 670 survey responses were received, 214 indicated that they had not been involved in a technology transaction with their current employer, leaving 456 usable responses.

response rate and the fact that the survey frame approximated a census of relevant firms and TTOs, we believe the likelihood for non-response bias to be low.

Each survey participant was asked to provide information on the most recent completed and the last abandoned negotiation. All negotiations contained in the dataset have been the subject of serious negotiations; cold calls to potential buyers that progressed no further are not sampled. We asked about the last transaction (as opposed to letting the respondents choose which transactions to report) ensures that the transactions in the sample are not systematically correlated with their size or with their importance to respondents' organizations. Note also that, by design, about half of our dataset are completed transactions (executed contracts) and half the contracts covered negotiations that were abandoned.

A distinguishing feature of our data is that we have information on contracts governing trades between businesses, rather than solely technology transfers from university TTOs to businesses. We focus first on the 330 executed contracts with complete information about *both* the buyer and seller. Buyer type and seller type data were obtained either from self-reported characteristics of the respondent or from a survey question about the counterparty. This information, combined with data on the characteristics of the technology, paint a comprehensive depiction of pre-commercial technology transactions in Australia during our sample period. Table 1 shows the average attributes of technology and trading partner for TTO and private sellers.

Table 1: Technology and buyer attributes by seller type, executed contracts

		Seller Type		
Technology Attributes		TTO	For-profit	All (count)
Late stage		72.1%*	85.1%	266
Seller (inventor) participation		55.1%*	39.0%	141
Buyer Attributes				
Buyer Type	Large	43.4%	43.3%	143
	SME	56.6%	56.7%	187
Total executed contracts		**49%**	**51%**	**330**

Note: Private sellers are either large or SME private firms. Equal means test based on two sided t test, assuming unequal sample variances. '' indicates that we reject the null hypothesis that the sample means are the same between TTO and private sellers.*

Survey respondents nominated the stage of development of pre-commercial technology between basic science; applied science; proof-of-concept; prototype; pilot manufacturing and other. Grouping these categories, we nominate early-stage technology as those belonging to basic and applied science, and close to market as those which have been developed beyond this point. 72.1 per cent of TTO sales of technology are late-stage technology, compared with 85.1 per cent for for-profit sellers.

Given the pre-commercial nature of the technology considered, the seller of the technology may be involved in further development. When required, contracts may stipulate ongoing seller involvement through either inventor participation clauses, or the inclusion of contract research deliverables. The second row of Table 1 reports that ongoing seller participation was included in 55.1 per cent of technologies sold by TTOs and 39.0 per cent by for-profit firms.

Turning now to the counterparty characteristics, the survey included information on the buyer type. Whether the buyer was a large or SME firm was nominated by the survey respondent. Sales to large firms made up 43.4 per cent of sales by TTOs and 43.3 per cent of sales by for-profit firms. The remaining sales went to SME firms.

The survey also included measures of the technologies' perceived value and risk. Respondents were asked to rank the feasibility of the technology and the existence of a market for the final product on a Likert scale, with anchors, 'very certain' (=1) to 'very uncertain' (=7). The combined average of these two measures is denoted 'Total risk'. Survey recipients were also asked to nominate their approximate valuation of the technology by selecting from a range of value intervals, with the mid-point taken as the 'Value' of the technology.[9] The averages of these two measures are presented in Table 2 for technology sold by TTOs and for-profit firms. TTOs appear to be involved in the sale of riskier technology than their for-profit counterparts are. These projects have a slightly lower average value than for-profit sold technology. Overall, the data suggests similarity in the nature of technology traded by private and TTO market participants.

Table 2: Average risk (1-7 Likert scale) and value of technology ($m), executed contracts

	Seller Type		
	TTO	For-profit	All
Average Total risk	3.23	2.94	3.09
Average Value	$1.28m	$1.39m	$1.34m

Table 3 depicts the distribution of contingent payments across the sample. 60.7 per cent of contracts included royalties and about 9 in 10 contracts include one form of contingent payment modes. Only 12.8 per cent of transactions include no contingent payments. Contracts in the market for pre-commercial technology are complex documents, reflecting both the

[9] The intervals were less than $100 thousand; between $100 thousand and $500 thousand; between; 500 thousand and $1 million; between $1 million and $2 million; and above $2 million. For the last interval, the value was assumed to be $3 million.

complexity of the goods transacted as well as the many nuanced functions payment mode are intended to perform.

Table 3: Number of contingent payment types, executed contracts

Contingent payment type	Number of contracts	%
Royalties		
- only	89	60.7
- with milestones	84	
- with equity	5	
- with milestones & equity	23	
Milestones only	57	17.3
Equity only	24	7.3
Milestones & Equity	6	1.8
None	42	12.8
Total executed contracts	**330**	**100**

Source: Australian Markets for Technology Survey, 2011.

Our sample covers instances where buyers and sellers entered into formal negotiations and draft contracts were developed. By engaging in costly negotiations, both parties reveal that ex ante they believed that there exists a set of contract terms that will deliver a non-negative surplus to both the seller and the buyer. Negotiations break down when new information is revealed (by one of the parties) which could relate to attributes of the technology, the objective function of the counterparty, or their outside options. In some instances negotiation breakdown will manifest as failure to agree on elements of the contract, such as price, exclusivity or mode of payment.

Our sample includes 315 abandoned contracts. Including the abandoned contacts, our sample covers 645 contracts over pre-commercial technology in Australia between 2009 and 2011 with a full set of controls. We cannot comment on the welfare implications of abandoning negotiations.

The distribution of contract terms included on the 315 draft contracts (that were ultimately not executed) is presented in Table 4 below. Data describing the attributes of the technology and trading parties of these abandoned contracts are included in the appendix. These do not point to substantial differences between signed and unsigned contracts. Abandoned trades cover technology that are of similar risk profile, but at least among TTOs somewhat higher estimated value.

Table 4: Number of contingent payment types, unexecuted contracts

Contingent payment type	Number of contracts	%
Royalties		
- only	68	
- with milestones	111	62.2
- with equity	4	
- with milestones & equity	13	
Milestones only	30	9.5
Equity only	30	9.5
Milestones & Equity	9	2.9
None	50	15.9
Total abandoned contracts	**315**	**100**

4. Model and estimation

Since our explicit goal is to understand why royalties – as distinct from milestones, or equity, or upfront payments – are chosen by trading parties, we need to allow for optimising over multiple considerations using a library of contractual options. We are not aware of an existing stylised principal agent model with adequate richness to embody the dimensionality of the negotiated choice and complex trade-offs involved. We therefore estimate a reduced form model of contract design that nests key hypotheses of each class of model and thereby the hypotheses outlined in our framework section above.

Our estimating equation, and estimation approach is guided by what we know about the contracting process. An executed (i.e. signed) contract reflects the outcome of a negotiation between a buyer and a seller. Execution requires agreement about both the value and form of payment.[10] By revealed preference, an executed contract indicates that each party believes it is better off entering into the contract than walking away.

Each different contingent payment mode (royalties, equity and milestones) can achieve related but distinct objectives. For example, milestone payments and equity deals transfer subtly different types of risk, with the latter being restricted to codifiable downside risk. That is, although they perform related functions they are not necessarily direct substitutes. The distribution of payment types, as summarised in Table 3, suggests that modes of payment are far from perfect substitutes. Contracts represent the outcome of lengthy negotiations. Each party makes amendments to the draft repeatedly over the average nine months of negotiating period. We assume that the process can reasonably be summarised as the parties picking, from a menu of possible contracts, an option that overlaps the interests of both parties.

We begin with a simple linear model of the choice to include royalties in the contract of sale, irrespective of the other modes of payment stipulated. Subsequently, we will enrich the estimation to allow for the simultaneous choice of other payment modes. This baseline model is given by:

$$Royalties = f\left(\begin{matrix} TTO\ Seller, Large\ Seller, \\ Large\ Buyer, \\ Seller\ participation,\ Seller\ participation\ \times Large\ Buyer \\ Value, X \end{matrix}\right) + \varepsilon \qquad (1)$$

The dependent variable is coded 1/0 indicating whether the contract includes royalty payments as part of the vector of agreed payment modes. Key explanatory variables of interest

[10] While our focus is on mode of payment, contracts also document other aspects of the agreed transaction including warranties and exclusivity clauses.

correspond to our five hypothesis relating to: (1) allocation of risk; (2) transaction costs; (3) ongoing seller (inventor) participation; and (4) incomplete information.

Our variables are defined in the following manner.$TTO\ Seller$ is a dummy variable indicating that the seller is a TTO. Our interest in this variable is the disposition of TTO sellers to include royalty payments, controlling for attributes of the technology and trading partner. Although it is impossible to control for all relevant attributes of technology and buying agent by controlling for a rich array of attributes of the technology and of the negotiating parties we argue that a strong adherence to royalties after controlling for observable characteristics indicates an institutional preference.

$Large\ Buyer$ indicates that the technology buyer is a large for-profit company. Our interest here is the interaction $Seller\ participation \times Large\ Buyer$ where $Seller\ participation$ indicates whether the contract includes either inventor participation clause or contract research. As discussed, equity may not be a viable option for encouraging inventor (i.e. seller) participation in large firms and royalties may be invoked instead ($Large$ Seller is included so that the excluded case is $SME\ Buyer$ and $SME\ Seller$).

$Value$ is equal to the natural logarithm of the approximate valuation mid-point plus one. This variable is included to test the assumption of Savva and Taneri (2014) that mutually agreed terms will include royalties when the technology is low-value (because low value is associated with a low elasticity of demand).

Control variables $(\boldsymbol{X})$ comprise $Late\ stage$ that indicates if the technology was described as proof-of-concept, prototype, pilot manufacturing or 'other'; and = 0; if described as basic or applied science. $Patent$, controls for whether the technology is covered by a granted patent at the time of sale. We also control for technology area (biotechnology; chemicals; drugs and medical; electronic; mechanical; software, and 'other'). $\boldsymbol{\varepsilon}$ is uncorrelated noise.

The decision to include royalty payments in the contract is not made in isolation. We also model a richer understanding of contract design by jointly estimating the use of royalties, equity and milestone payments. The model is given by:

$$\left.\begin{matrix} Royalties \\ Equity \\ Milestone \end{matrix}\right\} = f\left(\begin{matrix} TTO\ Seller, Large\ Seller, \\ Large\ Buyer, Value \\ Late\ Stage,\ Late\ Stage\ \times Small\ Buyer \\ Seller\ participation,\ Seller\ participation\ \times Large\ Buyer \\ Patent,\ Patent\ \times Small\ Buyer \\ Risk\ ,\ \ Technology\ Type, X \end{matrix}\right) + \varepsilon \quad (2)$$

In this case, the three dependent variables indicate the inclusion of each of the three types of contingent payments in the contract.

We also consider the statistical association between payment modes included in the contract and negotiation outcomes. Abandoning contract negotiations does not have a clear and unambiguous welfare implication. Sellers and buyers may go on to conclude successful transactions with alternative counter parties in subsequent negotiations. Nonetheless, we argue that the association between terms in the draft contract and negotiation outcomes can provide insight into common sticking points. For example, it is possible that trading parties simply find it easier to agree on royalties due to cultural norms and institutional experience. If this were the case, rational negotiators may choose to include royalties in the contract, despite the associated costs. The model is given by:

$$Executed = f\left(\begin{matrix} Royalties, Equity, Milestone, \\ Seller\ participation, X \end{matrix}\right) + \varepsilon \qquad (3)$$

Where $Executed = 1$ if the negotiation resulted in agreement and an executed (signed) contract and = 0 otherwise. The remaining variables are as above. In order to reveal any relationship between royalty payment inclusion and negotiation completion it is important to control for technology and trading party characteristics as there many pathways through which negotiation outcomes may differ between technology types.

The correlation between contract terms and negotiation outcome cannot be interpreted causally because the distribution of contract terms offered is not expected to be random. Payment modes included in the proposed contract no doubt reflect the preferences of the seller given the characteristics of the traded technology. It is plausible that these preferences are shaped by unknown factors that jointly determine whether royalties are included in the contract and the probability of contract execution. That is, even after controlling for technology and trading partner characteristics that are likely to influence the probability of contract execution, we are unable to rule out the possibility of extraneous factors influencing both royalty inclusion and negotiation failure.[11] Yet, the (partial) correlation between royalties and negotiation outcome can potentially provide *a priori* evidence as to whether royalties provide a positive role in facilitating deal execution.

In the absence of a compelling external instrument, we examine the potential causal role of royalties in negotiation breakdown using Lewbel's (2012) novel instrumental variables approach. Lewbel's approach effectively controls for unobserved factors that are likely to influence both the decision to include royalties in the draft contact and the likelihood of

[11] One can envision an identification strategy that relies on multiple failed (and successful) negotiations for each participant in the market, and the application of participant fixed effects that these data would enable.

contract execution. Instruments are generated from the auxiliary equations' residuals, multiplied by each of the included exogenous variables. Identification is achieved in this context by having regressors that are uncorrelated with the product of heteroskedastic errors (see Baum *et al.* 2012, Lewbel 2012).

5. Results

Probit estimates of Equation 1 are presented in Table 5. Column (1) presents the base case including only indicators of the types of buyers and sellers engaged in the sale. The model presented in column (2) incorporates a rich set of technology attributes that may explain the preference for royalty payment inclusion. For example, it is possible that TTOs are systematically associated with trades in technology which is at an earlier stage, with higher risk technology or technology in specific fields that lend themselves to royalty payments. We find however that the coefficient on $TTO\ Seller$ is quite similar to the parsimonious model, which is consistent with the view that the presence of royalties on executed contracts is a function of the preferences of TTO sellers rather than unique attributes of the technology that they sell. The model presented in Column (3) we include the interacted variables indicated in hypothesis 1c (small sellers x patent), 1d (small sellers x late stage); and 3 (large buyers x seller participation).

In each model, the coefficient on $TTO\ Seller$ is large and significant indicating that in general TTOs selling pre-commercial technology are significantly more likely to include royalties in the contract than private sellers, controlling for technology and market attributes as perceived by the participants in the negotiation. Given the rich information about technology included in the model the result is consistent with a view that TTOs preferences are indeed different from large firms.

Considering the role of risk allocation, we note that there is no statistically significant differences in the propensity for contracts involving small or large-firm buyers to include royalties (hypothesis 1b). Moreover, small (assumed to be risk averse) sellers are no more inclined to enter deals involving royalty where risk is mitigated due to the technology being late stage (hypothesis 1c). We also note that perceived risk associated with commercialising the technology is not found to have a statistically significant association with the presence of royalties on the contract.

Table 5: Dependent variable: Are royalties included in the contract of sale?

	(1)	(2)	(3)
BUYER LARGE	-0.115	-0.170	-0.192
	(0.145)	(0.153)	(0.213)
SELLER LARGE	0.149	0.271	0.662
	(0.259)	(0.272)	(0.465)
SELLER PRO	0.735***	0.816***	1.187***
	(0.151)	(0.166)	(0.387)
SELLER PARTICIPATION		0.00705	-0.0233
		(0.153)	(0.205)
SELLER PARTICIPATION X LARGE BUYER			0.0451
			(0.307)
LATE STAGE		0.420**	0.283
		(0.190)	(0.226)
LATE STAGE X SMALL SELLER			0.463
			(0.404)
PATENT		0.00334	-0.00220
		(0.162)	(0.218)
PATENT X SMALL SELLER			-0.0116
			(0.315)
LOG OF VALUE		0.0425	0.0447
		(0.0559)	(0.0560)
PERCIEVED RISK		-0.0458	-0.0441
		(0.0564)	(0.0567)
BIOTECHOLOGY		0.358**	0.359**
		(0.176)	(0.177)
CHEMICALS		-0.378	-0.374
		(0.253)	(0.253)
DRUGS & MEDICAL		0.0484	0.0447
		(0.196)	(0.197)
ELECTRONIC		0.243	0.236
		(0.266)	(0.268)
MECHANICAL		-0.00991	-0.00967
		(0.227)	(0.228)
SOFTWARE		-0.549***	-0.568***
		(0.195)	(0.196)

Observations	330	330	330

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Seller participation is not associated with royalties as a motivating mechanism, even when the buying firm is large (hypothesis 3). The signalling hypothesis of Saava and Tenari (2014) is not supported as we find no significant association between the respondent's estimate of the total value of the technology and the presence of royalties on the contract (hypothesis 4a). The results suggest some role for transaction costs. $Late\ stage$ technology is associated with a higher propensity for the signed contract to include royalties, consistent with hypothesis 2b.

Results of the jointly estimated model are reported in Table 6. All three equations are estimated simultaneously using a multivariate Probit model and include the full set of controls. Column (1) shows the coefficients of the royalty equation. Coefficients are similar to those reported in Column 2 in Table 4 above: contracts with a TTO seller are significantly more likely to include royalties than those contracts with large or SME sellers.

Columns (2) and (3) present the results where equity or milestone payments are the dependent variable. Contracts involving small buyers are more likely to include equity than those involving large buyers. This is consistent with equity being used to allocate risk to the less risk averse party. Though there are also practical reasons why paying equity share is simply not viable where buyers are very large. Contracts involving small buyers are less likely to include milestone payments (coefficient on large buyer 0.532). This is consistent with the use of milestones to transfer risk to the seller if these small buyers are uncertain about their future liquidity. Overall, we view the support for hypothesis 1 as limited.

Table 6: Why royalties? Determinants of payment mode, executed contracts

	(1) Royalties	(2) Equity	(3) Milestones
BUYER LARGE	-0.171	-0.697***	0.532***
	(0.153)	(0.191)	(0.149)
SELLER LARGE	0.265	-0.828**	-0.335
	(0.266)	(0.390)	(0.257)
SELLER PRO	0.815***	-0.475**	0.152
	(0.163)	(0.186)	(0.163)
LATESTAGE	0.412**	-0.0490	-0.0625
	(0.190)	(0.220)	(0.182)
PATENT	0.00565	-0.115	0.251
	(0.155)	(0.196)	(0.156)
LOG OF VALUE	0.0419	0.297***	0.201***
	(0.0550)	(0.0692)	(0.0564)
PERCEIVED RISK	-0.0458	0.209***	0.0798
	(0.0544)	(0.0662)	(0.0559)
SELLER PARTICIPATION	0.00611	0.351*	0.197
	(0.152)	(0.182)	(0.149)
BIOTECHOLOGY	0.359**	-0.0200	0.144
	(0.170)	(0.209)	(0.169)
CHEMICALS	-0.382	-0.597	0.131
	(0.258)	(0.399)	(0.246)
DRUGS & MEDICAL	0.0647	0.270	-0.121
	(0.199)	(0.222)	(0.187)
ELECTRONIC	0.240	-0.174	0.456*
	(0.253)	(0.370)	(0.277)
MECHANICAL	-0.00414	-0.102	-0.200
	(0.236)	(0.297)	(0.232)
SOFTWARE	-0.550***	0.0847	0.356*
	(0.187)	(0.240)	(0.194)
OBSERVATIONS	330	330	330

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
100 random variates drawn for calculating simulated likelihood

Risk is found to be positively associated with equity but not associated with milestones or royalties. This evidence opposes hypothesis 2. That equity is associated with high-risk projects reflects the concern regarding the technology being superseded or sold again during its development. Holding equity in this case hedges some of these risks. We view this as significant evidence that equity has a more important role in managing risk than concerns regarding transaction costs. This suggests equity is a risk allocation strategy rather than a method to manage transaction costs. However, consistent with the role of transaction costs, royalties are associated with late-stage technology.

The results provide no evidence for hypothesis 3, that large and diversified firms use royalties in place of equity to incentivise ongoing seller support with no statistical association between either royalties or equity with $Large\,Buyer\ \times Seller\,Participation$. That ongoing seller participation is positively associated with equity payments is consistent with the view that equity can be used to align post-contract behaviour of the sellers.

We find no support for hypothesis 4, that royalties are used to separate high from low value technologies. The results reveal that high-value contracts do tend to use equity payments (consistent with Bray and Lee 2000), but rather than coupling this with royalties (as suggested by Savva and Taneri 2014), they are coupled with milestone payments. We speculate that this is consistent with high fixed cost of valuation involved in equity deal. The value separation model does not offer a rational for the combination with milestone payments since milestone payments do not create the same value destroying distortion on sales as royalties.

Estimates of the model considering association between contract attributes and negotiation outcomes (equation 3) are shown in Table 7. Column (1) presents probit estimate and column (2) presents a linear probability model estimated using ordinary least squares with errors robust to arbitrary heteroscedasticity. The linear probability model provides coefficients that can be directly compared with the IV linear probability estimates that are consistent estimates of the local average treatment effect of royalties on contract execution, notwithstanding the potential for omitted variable bias already discussed (Angrist and Krueger, 2001). Column (3) presents the IV linear probability model based on the Lewbel (2012).

Table 7: Dependent variable: Contract executed

	(1)	(2)	(3)
ROYALTIES	-0.108	-0.0401	-0.294*
	(0.110)	(0.0418)	(0.170)
EQUITY	0.000689	-0.000543	0.0122
	(0.138)	(0.0532)	(0.178)
MILESTONE	0.0489	0.0186	0.0247
	(0.104)	(0.0397)	(0.196)
LATE STAGE	0.120	0.0450	0.0520
	(0.121)	(0.0458)	(0.0488)
RISK	-0.200***	-0.0767***	-0.0802***
	(0.0394)	(0.0145)	(0.0161)
PATENT	0.214*	0.0819*	0.0772
	(0.110)	(0.0422)	(0.0482)
BIOTECHOLOGY	0.204*	0.0782*	0.106*
	(0.120)	(0.0452)	(0.0600)
CHEMICALS	-0.0272	-0.0104	-0.0222
	(0.170)	(0.0636)	(0.0699)
DRUGS & MEDICAL	0.0347	0.0122	0.0183
	(0.130)	(0.0492)	(0.0551)
ELECTRONIC	-0.0501	-0.0202	-0.000243
	(0.178)	(0.0678)	(0.0705)
MECHANICAL	0.0576	0.0222	0.0313
	(0.162)	(0.0620)	(0.0624)
SOFTWARE	0.215	0.0820	0.0302
	(0.144)	(0.0548)	(0.0632)
Observations	645	645	645

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

These results show that, a higher level of risk is associated with lower probability that the contract is executed. The results provide no evidence that including royalties in the contract facilitates contract execution. In fact, the Lewbel based IV estimates indicate that including royalties actually diminishes the likelihood of contract execution. That is, controlling for observable characteristics of both the technology and the buyer and seller, the inclusion of royalty payments in a contract decreases the chances of that contract being signed in a significant way.

This result, combined with the previous finding that royalty inclusion is primarily driven by large seller and TTO preferences, hints to significant implications for trading parties and policy makers in the market for pre commercial technology. Given that large firms and TTOs play such a large role in this market, their eagerness to include a payment mode that is predictive of negotiation failure indicates that there are gains from trade left on the table in the market for pre commercial technology.

6. Conclusion

The market for pre commercial technology is characterised by uncertainty about the underlying technology, the need for an ongoing seller participation and asymmetric information. These trading hazards are managed using an array of contractual tools including various contingent payment modes. Of the available options, royalties are included in 6 in 10 contracts. We ask: why is this payment mode so prevalent in contracts for pre-commercial technology when it is generally held that equity can provide the same incentives and risk re-allocation without distorting output decisions (Jensen and Thursby 2001, Savva and Taneri 2014)?

Previous analysis of contracts in market for pre-commercial technology have been largely restricted to contracts governing technology transfer licences from universities (Jensen and Thursby 2001, Feldman *et al.* 2002, Siegel 2007, Dechenaux *et al.* 2011).[12] Consequently, it has not been possible to determine the extent to which the prevalence of royalties is unique to TTO sellers. We address this question using a sample of 330 completed and 315 abandoned technology contracts in the Australian market. Departing from a well-established literature on contracts for market-ready technology, our data are sourced from a comprehensive survey of

[12] An earlier literature considers licencing focused on mature (i.e., market-ready) technology (Caves *et al.* 1983; Macho-Stadler *et al.* 1996, Anand and Khanna 2000).

Australian buyers and sellers of immature technology that include private participants as well as TTOs.

The evidence presented provides little support for the role of risk allocation, incentivising ongoing inventor participation or separating high from low-value technologies. We find some support for the role of transaction costs, as perceived. The cost of negotiating and administering royalties is generally perceived to be lower, however, it is not at clear that the cost of revenues foregone are accounted symmetrically with potential losses from failed investment by buyers. Risk is associated with higher information cost is not found to provide an explanation to the role of royalties. However, information costs are likely to be high for early-stage technologies as well and early-stage technology is found to provide a partial explanation to the use of royalties.

We conclude by highlighting two findings (1) TTOs have a preference for royalties that is not explained by unobserved attributes of the technology or the trading parties; and (2) including royalties on the draft contract does not appear to increase the likelihood that the contract is executed – and may in fact prove a sticking point. Given the rich information about technology included in the model the result is consistent with a view that TTOs preferences are indeed different from large firms, though of course it not possible to be rule out unobserved systematic differences in the traded technology. The failure to observe any obvious improvement to negotiation outcomes when royalties are mooted suggests caution should be applied when practitioners claim that royalties provide the 'easy' and well understood option. It may be that university TTOs should reconsider their use of royalties in contracting over technology transfer. Consistent with previous theoretical arguments, our evidence suggests using equity and milestone payments in lieu of royalties wherever possible is associated with more executed contracts and potentially better outcomes for technologies on their path to market.

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Appendix 1 Supplementary descriptive statistics

		Seller Type		
Technology Attributes		TTO	For-profit	All (count)
Late stage		60.6%*	81.9%	224
Seller participation		40.6%	33.5%	117
Buyer Attributes				
Buyer Type	Large	40.0%	44.5%	133
	SME	60.0%	55.5%	182
Total abandoned contracts		**50.8%**	**49.2%**	**315**

	Seller Type		
	TTO	For-profit	All
Average Total risk	3.95	3.46	3.70
Average Value	$1.30m	$1.43m	$1.37m