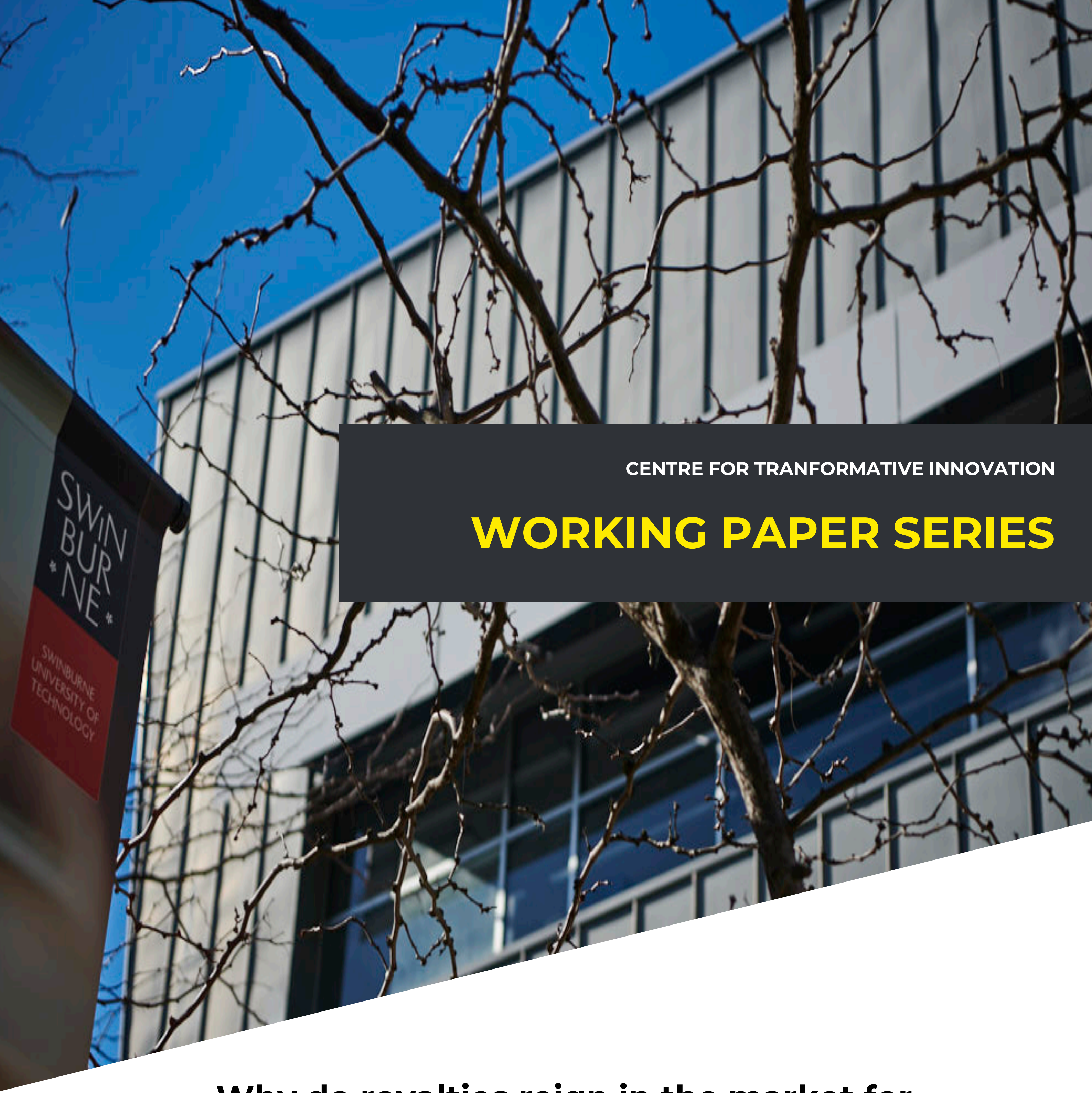

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Why do royalties reign in the market for technology?

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Abstract

Why do universities rely heavily on royalties in contracts governing technology transfer? Royalties are so ubiquitous that their utility may seem self-evident to practitioners. However, it is well recognised by contract theorists that royalties distort output decisions whereas milestone payments and equity payments do not. We shed light on this issue using systematic new data on contracts governing business-to-business as well as university-to-business transactions of early stage technology. These data suggest that the use of royalties reflect the specific organisational preferences of university technology transfer offices which may not be economically or managerially optimal.

Keywords: Contract design; market for technology

JEL: L24, D86, 032

1. Introduction

Transactions in pre-commercial technology – discoveries and technologies that need further development before use – are critical junctures in translation of basic research, both from the public research sector to industry and increasingly within industry itself (Arora *et al.* 2004, 2010, 2013; Chesbrough 2006, Savva and Taneri 2014, Reslinski and Wu 2016). This vertical separation of product development 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 typically blend upfront and contingent payments to manage trading hazards. 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 (Reslinski and Wu 2016).

Existing evidence on contract design for technology trades is limited to technology transfer licences from universities (Jensen and Thursby 2001, Feldman *et al.* 2002, Siegel 2007, Dechenaux *et al.* 2011).[1] For 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). Despite their popularity in practice, the drawbacks of royalties are well understood by contract theorists. Royalties, which are leveed on sales, distort output decisions driving a wedge between marginal revenue and marginal cost, thereby reducing overall project value.[2] Moreover, 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). Compounding this puzzle, it has been found that where universities take equity, the return is higher than royalty revenues (Bray and Lee 2000). There is also evidence 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? The main arguments put forward are that royalties can both shift risk back to the seller and incentivise ongoing inventor participation. However, it is increasingly recognised that most, if not all, arguments in favour of royalties can be made in relation to other contingent payment modes such as milestone or equity payments, which avoid the disadvantages associated with royalties (Jensen and Thursby 2001, Savva

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[1] An earlier literature considers licencing focused on mature (i.e., market-ready) technology and includes contracts between commercial actors (Caves *et al.* 1983; Macho-Stadler *et al.* 1996, Anand and Khanna 2000, Vishwasrao 2007.).

[2] Whether a royalty payment reduces a firm's profits depends on the elasticity of its demand curve but it would have to be very inelastic for a royalty to lead to greater profits than an upfront payment.

and Taneri 2014). Alternatively, royalties may be favored for non-economic reasons. Bray and Lee (2000) and Feldman *et al.* (2002), argue that universities 'over use' royalties because managers either lack experience, or, do not have the necessary institutional support for equity-based agreements. To date, these hypotheses remain untested due to lack of suitable data, most notably comparative data between technology transfer offices (TTOs) and the private sector. Consequently, it has not been possible to determine whether the prevalence of royalties is abnormally high among university sellers, given the nature of technology traded and counterparty.

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 as well as 66 semi-structured interviews with key decision makers in the market for pre-commercial technology in Australia. Our data on contracts were collected via a systematic survey of the market for pre-commercial technology in Australia, covering all forms of technology transfer including licencing, sale and spin-offs. To our knowledge, this is the first empirical study reporting systematic evidence on contracts for trade 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 exceptional among university TTOs or can be explained by the specific nature of the technology traded and its counterparty. As a small, open developed economy that is deeply integrated with the US technology market, and given the prevalence of highly ranked universities, the Australian context provides an excellent vantage from which to garner internationally relevant benchmarks.[3]

Our results support the hypothesis that TTOs have an institutional preference toward the use of royalties which is not economically or managerially optimal. Interviews revealed two relevant managerial norms at universities. First, respondents to our interviews reported that that TTOs have a preference for exposure to upside risk because blockbuster successes are often highly publicised and the reputational cost to a TTO employee who fails to capture a substantial share of a major blockbuster technology is likely to be large. In contrast, within a university, few invention disclosures are ever successfully traded so evaluating failure where no deal is signed is difficult.[4] The second relevant observation to come out of our 66 interviews is that TTO managers typically have the authority to sign contracts for milestone and royalty payments but not equity deals. Equity agreements need to be authorised by the peak governing body of the university and this additional tier of governance creates a disincentive for their use. Our analysis of executed contracts also supports the existence of institutional preference toward royalties. 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.

[3] Over and above the dominance of the United States in inward FDI, we observe that technology receipts from (and payments to) the United States account for about half Australia's OECD receipts (payments) (OECD 2013)
[4] The low cost of not signing a deal has also been observed by Feldman et al. (2002) and Arora et al. (2013).

Finally, our data suggest that far from being the 'easy option' royalties appear to be a sticking point for successful contract execution.

3. Data and descriptive statistics

To shed new light on what underpins the widespread use of royalties among TTOs, and to benchmark against trades between corporates we collected detailed data on 645 contracts governing the sale of pre-commercial technology[5] in Australia, executed between 2009 and 2011. The 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. Prior to collecting data on contracts, we undertook 66 semi-structured interviews during 2010 with the dual purpose of identifying market participants and collecting qualitative information on the preferences the functioning of the market. To collect systematic information about contract design, a structured survey was posted to 1,427 people active in the market for pre-commercial technology. The survey was administered to people in organisations that acted as negotiators and intermediaries in technology trading. 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).[6] In light of the high response rate and the fact that the survey frame approximated a census of relevant firms and TTOs we believe that the likelihood for non-response bias to be low.[7]

Respondents provided information on the most recent executed (within 12 months of negotiations) and the last abandoned negotiation (not executed after 12 months). 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.[8] Sampling 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. Depending on the respondent's role, they were asked to report as an intermediary representing a buyer or seller or both.

We focus first on the 330 executed contracts with complete information about *both* the buyer and seller. Buying and selling organisations are classified into three groups: small for-profit companies;

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[5] 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."
[6] 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.
[7] See Jensen et al. (2015) for further details on administration of the survey.
[8] The average duration of negotiations was nine months.

large for-profit companies and technology transfer offices of universities and public research institutions. Buyer type and seller type data were obtained either from self-reported characteristics of the respondent or from a survey question about the counter-party. 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]

Royalties are dues sellers receive on future sales of products embodying the technology.[9] Royalties are just one form of contingent payment that can be included in a contract. Milestone payments and equity are also contingent payments. A milestone payment is a fixed amount to be paid if a defined technical feasibility is demonstrated. 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 created to commercialise the technology. Table 4 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 complexity of the goods transacted as well as the many nuanced functions payment mode are intended to perform.

[Table 2]

Survey respondents also 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 this is 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.

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[9] Royalties are most commonly defined *ad valorem* on total value but is sometimes defined as a dollar amount per unit sold.

Turning now to the counter-party characteristics, the survey included information on the buyer type. According to Table 1, 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 firm buyers.

Table 3 shows that four in five contracts included intellectual property (IP), either the licence, sale or cross-license and about one in four was a R&D partnership. IP was more likely to be included when the sellers were from the for-profit sector. The most common technology group was biotechnology (43.6 per cent) followed by software (22.4 per cent).

[Table 3]

The survey also includes estimates of the technologies' commercial 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.[10] The averages of these two measures are presented in Table 4 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. These projects have a slightly lower average value than for-profit sold technology. The data illustrates that technology traded by private and TTO market participants have similar observable characteristics overall.

[Table 4]

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 counter-party, 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.

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[10] 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.

The distribution of contract terms included on the 315 draft contracts (that were ultimately not executed) is presented in Table 5 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 5 about here]

4. Model and estimation

Our goal is to assess whether TTOs' use of royalties can be explained by the nature of the technology traded or their trading parties relative to the preferences of businesses selling early stage technology. An executed (i.e., signed) contract reflects a mutually satisfactory outcome for both buyer and a seller.[11] In modelling contract design, we envision negotiating parties select from a menu of possible contracts an option that overlaps the interests of both parties in regards to multiple trading hazards.[12] We model contract design by jointly estimating three equations for the presence of each payment mode in the executed contracts (royalties, equity and milestone payments). The estimating equations are given by:

$$\left.\begin{matrix} Royalties \\ Equity \\ Milestone \end{matrix}\right\} = f(\text{TTO seller}, \text{X}\beta) + \boldsymbol{\varepsilon} \qquad (1)$$

Of principal interest is the disposition of TTO sellers to include royalty payments, controlling for attributes of the technology and trading partner. $TTO\ Seller$ is a dummy variable indicating that the seller is a TTO. We argue that a strong adherence to royalties, after controlling for observable characteristics of the technology and counterparty, indicates an institutional preference.

X represents a vector of control variables, informed by theoretical literature as well as our interviews. Broadly, these factors relate to: risk transfer; incentivising inventor participation; signalling and incomplete information; and, transaction costs. 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 fee and profit share (Gallini and Wright 1990; Bousquet *et al.* 1998; Sen 2005a, 2005b, Vishwasrao 2007, Crama *et al.* 2008, Dechenaux *et al.* 2011).[13] These studies also focus on a single *function* performed by contingent payments (risk sharing *or* signalling *or* transaction costs). The parsimony of these models serves to elucidate each contracting concern but comes at the cost of

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[11] While our focus is on mode of payment, contracts also document other aspects of the agreed transaction including warranties and exclusivity clauses.
[12] The distribution of payment types, as summarised in Table 3, suggests that modes of payment are far from perfect substitutes.
[13] A rare exception is Savva and Taneri (2014).

providing real-world guidance to practitioners. In the real world, negotiating agents routinely include a mix of contingent modes and grapple with multiple hazards simultaneously. We outline theoretical contracting considerations and how these inform our model design below.

Contingent payments – royalties, equity and milestones – shift project risk from the buyer back to the seller, relative to upfront payments. Contingent payment modes can generate joint surplus by allocating risk in a manner that reduces the joint cost of bearing risk. It is standard to infer the risk preferences of various trading parties based on their attributes (Allen and Lueck 1995, Ackerberg and Botticini 2002). The cost of bearing risk is generally lower for large, diversified firms including universities and public research organisations as they can bear the cost of failure. Several interview respondents advised that TTOs have a preference for exposure to upside risk[14] because the reputational cost to a TTO employee who fails to capture a share of value from a major blockbuster technology can be large, whereas the cost of not selling a technology is low. Each of the three contingent payment modes considered transfer subtly different forms of risk. Milestone payments typically act to insure the buyer against codifiable, technical early-stage risks, such as failed clinical trial results. Milestones do not give the seller (desirable) exposure to upside risk. By comparison, royalties and equity transfer both upside and downside risk to the seller (Bray and Lee 2000, Feldman *et al.* 2002). Risks transferred by royalties and equity also differ. Royalties are paid only when products are sold. A seller holding equity can monetize via recapitalisation or Initial Public Offering – to some extent regardless of whether a product bearing their technology is commercialized. The implication is that risk transfer via equity is highly limited where buyers are large.

Our model includes a measure of project risk $Risk$, which is the average of the respondent reported market and technology risk. We control for the size of each trading party (Large Buyer, Large Seller, Small Seller) Risk management considerations suggest large sellers (and TTO sellers) are positively associated with contingent payment modes (relative to small sellers) while large buyers to be negatively associated with royalties and milestones because a large buyer has lower cost of bearing risk.

The need to induce the seller to continue to lend intellectual support for the development of the technology is also a consideration in contract design (Jensen and Thursby 2001, Lach and Schankerman 2008). Our model also includes an indicator that the contract nominates ongoing inventor participation. The three contingent payment mode (royalties, milestones or equity) can incentivise ongoing inventor (seller) participation. Equity deals can be crafted to create very high-powered incentives for inventor participation if his or her equity share is significant. However, 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

[14] i.e., large windfall payments in the event of unforeseen value creation

requires non-verifiable (non-contractible) inventor input. Accordingly, we expect *contingent payments (milestone, equity or royalties)* will be more prevalent in trades requiring inventor participation. But royalties will dominate equity if the seller is a large corporation. We include an indicator for $Seller\ participation$ which indicates an inventor participation clause or contract research. We also include an interaction term $Seller\ participation\ \times Large\ Buyer$ to assess whether equity cannot be used to effectively motivate seller (inventor) participation because the correlation between equity value and project 'success' is weak for large diversified firms.

Signalling is another fundamental function of contingent payments hypothesised by theorists to determine contract design. By accepting remuneration contingent on project success, a party can signal its confidence in the technology. The predictions of signalling models depend on which party has more information. Principal-agent models have assumed 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 is scant. Since commercial success requires knowledge of both the market and the technology, there is no *a priori* reason sellers will be better informed than buyers.

Savva and Taneri (2014) argue that sellers can use royalties – and royalties alone – as a screening mechanism to identify high-value technologies under the strict assumption that high-value technologies are those with highly elastic market demand. In this case, royalties destroy more value for high-value technology. Therefore, by offering buyers a choice for the buyer to pay them either (a) with a high equity share or (b) with a low equity share plus a royalty payment; buyers of high-value projects will choose (a) in order to avoid royalty payments. The seller has successfully retained a higher equity share in contracts to buyers of high-value projects while still finding a buyer for low value projects. To test the signalling hypothesis of Savva and Tenari we include $Value$, the natural logarithm of the approximate valuation of the traded technology. If the hypothesis is correct, we expect royalties will feature on contracts over low-value technology, but not high-value technology.

No discussion of contract design is complete without considering transaction costs. Transaction cost considerations do not indicate an unambiguous advantage to royalties, though they do point to settings where royalties will be particularly problematic. Transaction costs comprise both valuation as well as on-going costs associated with monitoring, verification and enforcement of payments (Chueng 1969; Stiglitz 1974; Hallagan 1978; Leffler, Rucker, 1991). Valuation costs are similar across payment types.[15] The costs of enforcement and monitoring are low for upfront payments and milestone payments as milestone payments rely on agreed observable technical outcomes. The on-going costs of equity and royalties however can be considerable. Monitoring equity deals will be fraught if there is a perception that large joint project returns will be syphoned off as higher managerial bonuses in the buyer's company. In the case of royalties, the seller must be able to observe sales in products embodying the technology (or verify technology substitution). On the other hand, although audit provisions are routinely included in royalty contracts, they are seldom enforced and where litigation does occur, evidentiary standards for infringement can be very high.[16] 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). Our interview respondents advised that the accounting and enforcement 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. To account for these issues, our model includes buying party size (Large Buyer/ Large Seller). $Late\ stage$ indicates that the technology was described as proof-of-concept, prototype, pilot manufacturing or 'other'; and = 0; if described as basic or applied science. Transaction cost considerations predicts that royalties will be negatively associated with technology that is early-stage, due to difficulties defining the basis of payment.

In addition to the variables discussed above, our model includes control for patent protection and for technology area dummies (biotechnology; chemicals; drugs and medical; electronic; mechanical; software, and 'other'). The presence of a patent may also influence mode of payment because patents can create value for the buying firm even if the technology is not worked into a product as they can be used to establish freedom-to-operate; block competing technologies; or enhance a bundle of rights used for cross-licensing. However, in these cases, royalties will not be paid to the seller. Accordingly, the presence of a patent will affect whether the seller wants to avoid agreeing to a royalty payment. The appendix provides definitions of variable used in the models.

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[15] An accurate valuation is required to set optimal payments, regardless of the payment mode. In practice, valuation costs are generally explicit in the case of equity deals where it is routine for buying firm to amass detailed knowledge of the proposal. Practitioners report that royalty rates are often based on a 'rules of thumb' rather than project specifics or careful valuation. However, there is no reason to believe a rate derived without reference to value is economically optimal.

[16] For example, 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.

5. Modelling negotiation outcomes

As well as modelling the terms of executed contracts, we also consider the statistical association between payment modes included in draft contracts and negotiation outcomes. 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. We are however cognisant that abandoning contract negotiation does not have a clear and unambiguous welfare implication. In some cases, sellers and buyers may go on to conclude successful transactions with alternative counter parties in subsequent negotiations. If, however, our sample of negotiations are representative of these further negotiations, then we expect that further negotiations will exhibit the same properties as our sample.

This second model is given by:

$$Executed = f(Royalties, Equity, Mile\ stone, X\beta_2) + v \quad (2)$$

where $Executed = 1$ if the negotiation resulted in agreement and an executed (signed) contract and = 0 otherwise; and v is uncorrelated noise. In addition to modelling the role of contract terms the model includes the range of observables, X, about the technology described above.

Although the statistical association between royalties and negotiation breakdown (or success) can potentially provide *a priori* evidence as to whether royalties provide a positive role in facilitating deals, the implied relationship 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. 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.[17] 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 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).

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[17] 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.

5. Results

All three equations are estimated simultaneously using a multivariate Probit model and include the full set of controls. Results are reported in Table 6. Column (1) shows results for determinants of royalties form part of the contract; column (2) models whether equity payments form part of the contract; and, column (3) shows results of the model for whether the contract includes milestone payments. A correlation matrix of variables is also given in the appendix.

[Table 6]

Our key result is that contracts involving sales by TTOs are more likely to include royalty payments even controlling for a rich set of observable attributes of the traded technology and trading agents. This is consistent with the argument of Bray and Lee (2000) that TTOs 'overuse' royalties as a mode of payment. Though we concede that, it not possible to rule out unobserved systematic differences in the traded technology, despite the richness of our model.

Risk management is a commonly mooted rationale for the use of royalties. The results indicate no statistically significant association between large sellers and royalties, apart from the noted overuse by TTO sellers. The result that large sellers are equally likely to sign contracts including royalties and milestone payments as small sellers is difficult to reconcile with risk management being a key factor in determining contract design. Large sellers are found to be less likely to enter into contracts including equity payments than small sellers. The results also indicate that large buyers are positively associated with milestone payments, indicating that large buyers are using milestones to shift risk back to the seller more than small buyers, the opposite of what is predicted by minimising cost of bearing risk. The results indicate that TTO seller is positively associated with royalty payments but not equity deals giving little support that the high prevalence of royalties on contracts from TTO sellers reflects a preference for exposure for upside risk.

Another rationale put forward for including royalties on the contract governing the transfer of early-stage technology is that royalties can incentivise ongoing inventor participation. We find no association between royalties and inventor participation. However, the results show that the need for ongoing seller participation is positively associated with equity payments. This is finding is consistent with the view that equity can be used to align post-contract behaviour of the sellers. Delving further into the issue of motivating ongoing inventor participation, we have argued above that equity cannot effectively be used to motivate seller contribution to development where the buyer is large, possibly indicating a unique context where royalties have some advantage. The results indicate no statistically significant relationship between association between either royalties or equity with the interacted term $Large\ Buyer\ \times Seller\ Participation$.

We also find no support for the theoretical conjecture of Savva and Tenari (2014) that royalties are used to separate high- from low-value technologies. The results reveal that contracts over high-value technologies are more likely to include equity payments and milestone payments rather than royalties. Of course, we had no strong prior that this should not be the case – although Savva and Taneri's (2014) conjecture relies entirely on the untested assumption is that higher value technologies exhibit higher elasticity of demand – and this simply may not hold in practice. 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 make up 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 of this (very high value and highly inelastic).

The control variables provide further interesting insights. The perceived riskiness of the technology is found to be positively associated with equity contracts but having no significant influence on the decision to include royalties. The importance of considerations of transaction costs in contract design is partly supported by the data in that we see, *ceteris paribus*, royalties included in the contact less often where technology is early-stage.

We now turn to consider determinants of contract negotiation outcomes. Table 7 shows estimates of the model considering association between contract attributes and negotiation outcomes (equation 3). Column (1) presents Probit estimates 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 (Angrist and Krueger, 2001). Column (3) presents the preferred IV linear probability model based on the Lewbel (2012)**.**

[Table 7]

The results presented in Table 7 show that, a higher level of risk is associated with a 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 IV estimates indicate that including royalties diminishes the likelihood of contract execution. That is, considering potential simultaneity and controlling for observable characteristics of both the technology and the buyer and seller, the inclusion of royalty payments in a contract actually decreases the chances of that contract being signed in a significant way.

6. Concluding remarks

It is increasingly common for technology to pass between several companies on its way to market Potential gains from trade in early-stage technology are large but are difficult to achieve due to pervasive contracting hazards. These trading hazards are managed using an array of contractual tools including various contingent payment modes. Of the available options, royalties are by far the most prevalent contingent payment mode for contracts governing transfer of early-stage technology from universities. We ask: why are royalties 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).[18] Consequently, it has not previously 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 were collected via a comprehensive survey of Australian buyers and sellers of immature technology resulting in a random sample of contracts governing both business-to-business sales as well as TTO-to-business sales.

Consistent with theoretical arguments made by scores of previous scholars, new evidence presented in this paper indicates that negotiators should consider using equity and milestone payments in lieu of royalties to manage contracting hazards wherever possible. This may require delegating the authority to enter equity deals to a lower tier of management than is currently the case. The data confirm the extensive use of royalties by TTO sellers. Royalties are included in three in four contracts when the seller is a TTO but that royalties feature in fewer than half of all contracts when the seller is a business, despite considerable overlap in the nature of the technology sold by TTOs and for-profit businesses. Inferring the preferences of TTOs from our random sample of 330 executed contracts, we find that TTOs exhibit a preference for royalties that is not explained by observable attributes of the technology or the trading parties.

Our results also indicate that nominating royalties on a draft contract does not increase the likelihood that the contract is executed – in fact, it is associated with an increase in the likelihood of negotiation breakdown suggesting that rather than smoothing the path to agreement, royalties commonly prove a sticking point. The failure to observe any obvious improvement to negotiation outcomes when royalties are mooted suggests caution should be applied when practitioners claim that

[18] 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).

royalties represent the ‘easy’ payment option. Indeed, TTO’s eagerness to include a payment mode (royalties) that predictive of negotiation failure suggests there may well be gains from trade left on the table in the market for pre commercial technology.

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APPENDIX

Appendix Table A –Technology and buyer attributes by seller type, abandoned contracts

		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**

Appendix Table B –Average risk (1-7 Likert scale) and value of technology ($m), abandoned contracts

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

Appendix Table C – Correlation matrix between explanatory variables

	Buyer large business	Buyer SME	Seller TTO	Seller large business	Seller SME	Seller participation	Late stage	Patent	Value	Total risk	Biotechnology	Chemicals	Drug & medical	Electronic	Mechanical	Software
Buyer Large business	1															
Buyer SME		1														
Seller TTO	-0.0063	0.0063	1													
Seller Large business	0.1140*	-0.1140*		1												
Seller SME	-0.0611	0.0611			1											
Seller (inventor) participation	-0.0391	0.0391	0.0706	-0.0567	-0.0385	1										
Late stage	0.0478	-0.0478	-0.2078*	0.0151	0.2035*	-0.0492	1									
Patent	0.0428	-0.0428	-0.1635*	0.0798	0.1198*	0.0081	0.0162	1								
value	0.2217*	-0.2217*	-0.0489	0.0925	-0.0048		0.0841	0.2177*	1							
Total risk	-0.0195	0.0195	0.0445	-0.0737	-0.0019	0.0817	-0.1347*	-0.1568*	-0.1653*	1						
Biotechnology	0.0166	-0.0166	0.0659	-0.1145*	0.0004	0.0273	-0.2373*	0.1660*	0.1754*	0.0242	1					
Chemicals	0.0725	-0.0725	0.0654	0.0758	-0.1117*	-0.0567	-0.0237	0.0798	0.0995	0.0243	-0.0937	1				
Drug & medical	-0.0224	0.0224	-0.0024	0.0572	-0.0314	-0.0022	0.0533	0.0184	0.1198*	-0.0149	0.0854	0.0045	1			
Electronic	0.0731	-0.0731	-0.077	0.0673	0.0389	0.0493	0.0121	0.0204	-0.0014	0.1129*	-0.2097*	-0.0364	-0.1078*	1		
Mechanical	0.0147	-0.0147	0.0096	0.0283	-0.0265	0.0147	0.0425	-0.0061	-0.0538	0.0541	-0.2705*	0.0283	-0.1193*	0.2866*	1	
Software	-0.0018	0.0018	-0.1396*	0.0976	0.0849	-0.0557	0.0489	-0.1597*	-0.1226*	-0.0059	-0.3467*	-0.1238*	-0.1148*	0.2275*	0.0426	1
'Other'	0.0433	-0.0433	0.022	-0.01	-0.0166	0.0384	0.0794	0.0347	-0.0538	-0.0296	-0.3385*	0.0172	-0.1798*	-0.0454	-0.1079*	-0.1160*

Appendix Table D – Variable definitions

Characteristics	Definition
Contract executed	1 if transaction was successfully executed within 12 months; 0 if abandoned
Respondent seller	1 if survey respondent was acting on behalf of the technology seller; 0 if otherwise
Respondent buyer	1 if survey respondent was acting on behalf of the technology buyer; 0 if otherwise
TTO	1 if business development unit of university or research institute; 0 if otherwise
Large	1 if survey respondent identified party as Large company; 0 if otherwise
SME	1 if survey respondent identified party as small or medium company; 0 if otherwise
Royalties	1 if proposed contract included royalties on sales; 0 if otherwise
Equity	1 if proposed contract included equity interest; 0 if otherwise
Milestone	1 if proposed contract included milestone payments; 0 if otherwise
Seller participation	1 if proposed contract included ongoing inventor participation; 0 if otherwise
Value	What was the approximate valuation of the technology? <$100k; $100k-$500k; $500k-$1m; $1m-$2m; >$2m; Unsure
Risk	Mean [Likert scale of 1 (certain) to 7 (very uncertain) of the technical feasibility of the transacted technology + Likert scale of 1 (certain) to 7 (very uncertain) of the market demand for the transacted technology]
Late stage technology	1 if technology was described as proof-of-concept, prototype, pilot manufacturing or 'other'; 0 if basic science, applied science
Patent	1 if at time of negotiation the technology has a registered patent; 0 if otherwise
Technology area	
Biotechnology	1 if area of technology was biotechnology; 0 if otherwise
Chemicals	1 if area of technology was chemicals; 0 if otherwise
Drugs & medical	1 if area of technology was drugs and medical; 0 if otherwise
Electronic	1 if area of technology was electronic; 0 if otherwise
Mechanical	1 if area of technology was mechanical; 0 if otherwise
Software	1 if area of technology was software; 0 if otherwise
Other	1 if area of technology was other; 0 if otherwise

Main paper tables

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.*

Table 2: Transaction Characteristics (Total executed contracts, N=330)

	Seller type		
	Technology transfer office (TTO) (%)	For-profit (%)	All transactions (%)
Type of transaction [a]			
License of IP	49.4	74.1	62.1
Sale of IP	17.5	12.4	14.9
Cross-license of IP	5.6	3.5	4.6
Contract research	11.3	27.1	19.4
Sale of technical know-how	15.0	12.4	13.6
Majority purchase of whole company	9.4	0.6	4.9
R&D partnership	25.0	25.9	25.5
Other	11.3	2.9	7.0
Technology [a]			
Biotechnology	40.6	46.5	43.6
Chemicals	7.5	11.2	9.4
Drug & medical	18.1	18.8	18.5
Electronic	12.5	7.7	10.0
Mechanical	13.1	13.5	13.3
Software	28.1	17.1	22.4
'Other'	16.9	18.2	17.6
Number of observations	**170**	**160**	**330**

Note: [a] multiple responses permitted.

Table 3: 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 4: Number of contingent payment types, executed contracts

Contingent payment type	Number of contracts	%
Royalties		
- only	89	
- with milestones	84	60.7
- 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.

Table 5: 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**

Table 6: Dependent variables: Royalties, Equity, Milestones in executed contract.

	(7)	(8)	(9)
VARIABLES	Royalties	Equity	Milestones
Buyer Large	-0.200	-0.680**	0.553***
	(0.213)	(0.293)	(0.207)
Seller Large	0.266	-0.827**	-0.336
	(0.265)	(0.389)	(0.257)
Seller TTO	0.814***	-0.475**	0.152
	(0.164)	(0.186)	(0.163)
Seller Participation	-0.0206	0.362*	0.216
	(0.204)	(0.216)	(0.197)
Large Buyer X Seller Participation	0.0604	-0.0322	-0.0432
	(0.306)	(0.383)	(0.296)
Late Stage Technology	0.413**	0.0496	0.0626
	(0.190)	(0.220)	(0.182)
Patent	0.00132	-0.114	0.254
	(0.158)	(0.193)	(0.158)
Log (Value)	0.0421	0.297***	0.201***
	(0.0551)	(0.0686)	(0.0564)
Total Risk	-0.0450	0.209***	0.0793
	(0.0546)	(0.0669)	(0.0561)
Biotechnology	0.360**	-0.0205	0.143
	(0.170)	(0.209)	(0.169)
Chemicals	-0.382	-0.597	0.130
	(0.258)	(0.399)	(0.246)
Drugs & Medical	0.0632	0.270	-0.119
	(0.199)	(0.222)	(0.186)
Electronic	0.236	-0.173	0.460*
	(0.253)	(0.373)	(0.276)
Mechanical	-0.00340	-0.101	-0.200
	(0.236)	(0.296)	(0.231)
Software	-0.552***	0.0869	0.357*
	(0.187)	(0.233)	(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

Table 7: Dependent variable: Contract executed / not executed (1/0)

	(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