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Abstract

In this article, we examine contract efficiency in a complex contractual environment for services characterized by cost uncertainty and an unknown level of service provision. Using data on water and sewerage network maintenance services contracts from two Melbourne water retailers, we compare the expenditure across fixed-price and cost-plus service contracts. The results suggest that the fixed-price contracts outperform the cost-plus contracts, thereby confirming the standard result that efficient contracts trade-off risk for incentives.

1. Introduction

Standard formulations of procurement contract problems analyse the tension between providing performance incentives while allocating risk appropriately (Holmström 1979; McAfee and McMillan 1986). The standard model examines this problem in the context of procuring a single indivisible good that is easily defined but is characterised by uncertainty in the cost of production. In many real-world contracts, however, the procurement environment looks rather different. Consider public transport, road maintenance or health services. Such services have unobservable quality characteristics and the level of demand is often unknown *ex ante*. The presence of demand uncertainty here creates substantial contracting problems since services cannot be inventoried and contracts for these essential services typically require service providers to meet all levels of demand, even if there are large demand spikes.[1] In this article, we examine whether the standard risk-incentive trade-off holds in such complex contractual environments using a unique data set collected for this purpose.

Existing empirical work on the predictions of contract theory has been undertaken on incentives and contract design *within* firms (for a survey, see Prendergast 1999), on optimal contracts in specific labour contexts such as sales (Andersen and Schmittlein 1984; John and Weitz 1989), executive employment (Aggarwal and Samwick 1999), manufacturing (Lazear 2000) and agriculture (Allen and Lueck 1992, 1999) and on contractual relationships *between* firms (Brickley, Dark and Weisbach 1991; Lafontaine 1992). Overall, however, the evidence on the trade-off is mixed – some empirical work has demonstrated a trade-off, while other research has demonstrated a positive relationship or no relationship (see Lafontaine and Slade 2001; Prendergast 2002). This has led some to argue that: "…it is only fair to say that the empirical validation of [contract] theory has long lagged behind the theoretical work" (Chiappori and Salanie 2000, p.1).

[1] Such spikes may occur, for example, if there are disease outbreaks or if there are severe weather episodes which affect demand for emergency services. The standard approach of raising price to dampen demand is not possible here because of the political and social welfare implications of raising prices for essential services.

Empirical economists have had trouble in verifying the predictions of contract theory for a variety of reasons. For example, observed correlations between contract type and cost reductions may be explained by simultaneity rather than causality (Chiappori and Salanie 2000). Another empirical difficulty relates to the possibility of endogenous matching of contracts with agents. Recent work suggests that if some agents are risk-neutral rather than the standard assumption of risk aversion, the principal and agent may be "matched" according to their relative risk aversion, which can't be directly measured (Ackerberg and Botticini 2002). Others have also argued that the failure to observe the risk-incentive trade-off may be due to the fact that extrinsic rewards can crowd out intrinsic motivation (see Frey and Jegen 2001; Benabou and Tirole 2003); an effect which is typically overlooked in economic models of contract efficiency (however, see Murdock 2002).

There are also significant data constraints associated with verification of the risk-incentive trade-off since the terms and conditions of contractual arrangements are typically commercially sensitive. In this article, we overcome this problem by constructing a unique data set from commercial contracts implemented by two corporatised[2] water retailers in Melbourne, Australia for the maintenance of their water and sewerage networks. We were able to obtain data at the individual activity level, not just at the aggregate contract level, which provides us with a richer data set. This allows us to compare the risk-incentive trade-off across the set of maintenance activities instead of just conducting an aggregate level analysis. Demand and cost uncertainty exist in this contractual environment since the demand for maintenance activities depends on rainfall, temperature, and the age of the assets and the cost of each activity depends on the complexity of each job.

There are, however, a number of limitations of the data which constrain our ability to analyse other interesting contracting problems. For example, we are unable to evaluate whether fixed-price contracts provide low-powered incentives for quality (Hart, Shleifer

[2] Corporatisation refers to the process whereby public agencies are subjected to performance measures similar to private sector firms, and management of these entities have been given contracts that reflect these performance measures in some form. However, the government retains ownership of the agency and its assets. In the past two decades, many public utilities in Australia have been corporatised.

and Vishny 1997; Holmström and Milgrom 1991). Similarly, we were unable to collect data on *ex post* renegotiation costs (or other transaction costs) despite the fact that the complexity of the task and the choice of contract type may have implications for the magnitude of such costs (see Crocker and Reynolds 1993; Bajari and Tadelis 2001). Repeated interactions and firm reputation, whose effects on contract choice have been analysed elsewhere (Banerjee and Duflo 2000; Corts and Singh 2004) have not been considered here because our data is only for two contract periods.

The structure of the paper is as follows. In section 2, we describe the contractual environment, which is characterized by the presence of both cost and demand uncertainty. A description of the maintenance services activities and the construction of the data set is then undertaken in section 3, followed by the empirical model to be estimated. Section 4 presents results of the econometric model and analysis of the findings. The results suggest that, even in complex contractual environments characterised by high levels of uncertainty, efficient contracts involve trading off risk for incentives. Finally, some conclusions are presented in section 5.

2. The Contractual Environment

The reform of the Victorian water industry, which was introduced by the passing of the *Water Industry Act 1994*, was aimed at introducing a greater degree of commercialisation and improving customer service levels in the industry. The central platform of the Victorian Government’s water reform package was the separation of Melbourne Water into a water wholesaler and three new corporatised water retailers (City West Water, Yarra Valley Water and South East Water). Prior to corporatisation, the Government outsourced the maintenance of the water and sewerage infrastructure. After the initial contract period, the retailers were then free to choose their own contract provider and type of contract. The retailers and the wholesaler remained in Government ownership, but they were provided with incentives to improve performance. Although the retailers could not compete directly for end-customers, they were subjected to ‘yardstick competition’, where the yearly results on key performance indicators for each retailer were published by the newly created regulatory authority, the Office of the Regulator-General.

There are two types of contracts used by the water retailers: fixed-price and cost-plus contracts. In the case of a cost-plus contract, the agent is paid for any actual costs incurred per unit of maintenance activity and hence, is fully compensated by the principal even if the actual number of hours per job is greater then the expected level. Thus, in a cost-plus contract, there is a moral hazard problem since the agent has no incentive to put in effort to reduce costs. The total payment made by the principal to the agent is simply the number of hours work multiplied by the hourly charge, plus any non-labour costs (including overheads).

Alternatively, in a fixed-price contract, the agent is paid a price per unit of output for a job based on the specification proposed by the principal. Unlike the cost-plus contract, the agent is not reimbursed if the actual number of hours is greater than the expected and thus they bear the risk of any cost uncertainty. In this situation, the agent is the residual claimant and will choose the level of effort to minimise cost since the agent takes the output unit-price as given at the time of choice of effort. Thus, in a fixed-price contract, the agent will put in cost-reducing effort up until the point where the marginal cost of doing so equals the marginal benefit (which depends on the extent to which costs are able to be reduced by increasing effort). Since the agent is risk-averse, a risk premium based on the variance of the distribution of costs is incorporated into the output unit-price. The payment made by the principal to the agent is simply the output unit-price multiplied by the number of activities performed plus a lump sum for all non-labour costs (which includes overheads).

There are a couple of differences between the contractual environment considered here and the standard environment. In most standard contract models, the only risk considered is the uncertainty associated with the cost of the project: it is assumed that demand is known. While contracts for goods usually state the number of required products, the number of units required in many service contracts is often unknown *ex ante*. For some services, the level of demand can be specified: for example, a cleaning contract may specify the number of times per week that an office must be cleaned. However, the demand for many services is derived and therefore cannot be determined *ex ante*[3]. In the contractual environment considered here, both demand and cost uncertainty are present. Costs are uncertain since not all water main leaks are the same; some may be deeper underground (or under a road) and are, therefore, more expensive than the average repair job. Demand is uncertain since it depends on variation in temperature and rainfall. Very dry weather, for example, is known to increase the frequency of burst mains because the ground shrinks as moisture is removed from the soil, thereby cracking the pipes.

When demand for a service is derived, highly uncertain *and* the service is essential – maintenance of the sewerage network, for instance, is an essential service since system failures can cause serious health problems if not fixed – the agent must agree to meet any level of demand. This creates a problem for the agent: since services cannot be inventoried and factors of production are not perfectly flexible, the agent must choose a capacity level *ex ante*, but demand is only revealed *ex post*. Therefore, if demand is much lower than the agent expects, the agent must bear the cost of holding excess capacity. Conversely, if demand is much higher than expected, the agent must go back to the market and obtain additional inputs. If these resources are highly specialised, both the upside and the downside risk associated with demand uncertainty will be costly for the agent to bear. Thus, the variance of demand affects the agent's capacity utilisation.

3. Empirical Framework

In order to test whether fixed-price contracts are more efficient than cost-plus contracts, we use data collected from maintenance service contracts at City West Water and Yarra Valley Water. Both of the water retailers are responsible for a geographical region in metropolitan Melbourne. City West Water provides water and collects sewage from an area covering 580 square kilometres, while Yarra Valley Water provides the same services to an area covering 4,034 square kilometres. As described below, there are

[3] For example, IT maintenance service contracts typically stipulate that the provider is to maintain the system and fix all network faults for a specified period. The exact number of maintenance activities in this case is unknown since it is derived from the number of system failures. Some IT contracts, therefore, limit the number of service calls allowable under the contract.

significant differences in these areas – the water retailers cover urban, suburban and semi-rural areas.

3.1 Description of Maintenance Service Activities

Two types of maintenance service were included in the contracts: water supply services and sewerage services. Water supply services may be disrupted when damage is caused to a water main, which is a conduit used to convey water under pressure. A water main is generally of diameter 40mm to 300mm, and is made of any one of a number of materials: cast iron, asbestos cement, mild steel or high density polyethylene. Water mains are joined together using various techniques, such as soldering, riveting and welding, depending on the type of material the main is constructed from. It is the contract service provider's responsibility to repair burst and leaking water mains. Such failures are affected by climatic conditions: a temperature increase, for example, can cause the earth to dry out and depending on the type of soil, cause ground movement that damages pipes. Water supply failures are also affected by the age and condition of the assets themselves.

Similarly, the contract service provider is responsible for repairing any damage to sewer mains, which are conduits used to convey sewage from households and businesses to sewage treatment plants. Sewer mains also vary in their size (100mm up to 600mm), their depth underground (0-3m) and the type of materials they are constructed from (vitrified clay, concrete and unplasticised polyvinyl chloride). Damage to sewer mains can be due to natural failure of the joins between lengths of sewer mains, but can also be affected by climatic conditions since tree roots often infiltrate sewer mains looking for water and other nutrients during times of low rainfall. It is important that repairs to damaged sewer mains be conducted in a timely fashion since untreated sewage is a major public health risk.

Repairs to the water and sewerage assets can be classified as either reactive or preventative maintenance. Reactive maintenance is work undertaken in response to reported system failures such as those described above. This type of work is characterised by high levels of both cost and demand uncertainty – the number and cost of future system failures is unknown ex ante since it is dependent on random variables such as temperature variation and the amount of rainfall, and other factors such as the age and condition of the assets. Preventative maintenance, on the other hand, relates to scheduled repairs of the network. Activity levels and the total budget for preventative maintenance are determined by the retailers in each financial year[4]. Thus, uncertainty is not a feature of preventative maintenance work since the contractor knows with certainty how much asset refurbishment work will be performed in each year. The analysis presented here focuses on the reactive maintenance side of the operation.

In order to deal with the health and safety aspects of damage to water and sewerage supply services, the service contracts are regulated by the government. As a result, all reactive maintenance activities are prioritised according to their severity. Priority 1 failures are defined as complete failures in the system, and are generally caused by a major break or blockage of the water/sewer main. They typically result in major property damage, risks to public health, and a significant loss of water. As a result, the contractors are required to respond to 90 per cent of such failures within 1 hour, and to restore the service within 5 hours. Priority 2 failures are defined as partial failure of the system, which is typically caused by a leaking water main or a partial blockage of a sewer main. Service providers are required to respond to 95 per cent of such failures within 3 hours, and to restore services within 24 hours. Priority 3 activities are defined as all non-urgent maintenance activities, which may be repaired within 14 days.

The analysis presented here focuses on the contractual arrangements at both Yarra Valley Water and City West Water over two contract periods: 1993-1996 and 1996-2001. A summary of the contract service providers in each period for both water retailers is presented in Table 1. As can be seen from the Table, the two water retailers swapped service providers[5] in 1996 and at the same time, City West Water changed the structure

[4] Although the budgets for these two classes of maintenance activities are separated, there is a relationship between the two since low levels of preventative maintenance generally increase the frequency of system failures. Allowing the contractor to determine the level of preventative maintenance may, therefore, be undesirable since it provides a perverse incentive to under-invest in preventative maintenance. This problem is overcome here since the retailers determine expenditure on preventative maintenance.

[5] For confidentiality reasons, we have not reported the names of the individual contract service providers. Rather, we have referred to them as Company A and Company B.

of its maintenance services contract from a fixed-price contract to a cost-plus contract. This provides us with enough variation to analyse the effects of various explanatory variables on contract efficiency.

Table 1: Details of Contract Service Providers, 1993-2001

	WATER RETAILERS	
Contract Details	**City West Water**	**Yarra Valley Water**
1993-1996		
Service Provider	Company A	Company B
Contract Type	FP	FP
1996-2001		
Service Provider	Company B	Company A
Contract Type	C+	FP

3.2 Data and Econometric Model

Ideally, analysis of the optimal contract would be undertaken using a large panel data set of maintenance service contracts encompassing several locations, different contractors and different contract types. This would allow other factors that may affect contract efficiency to be examined – factors such as the whether maintenance services are in city, suburban or rural areas; the age and condition of the infrastructure; soil types; and weather variables such as temperature and rainfall. While data on maintenance service expenditure in a cross section of water authorities in Australia exist, it is difficult to obtain since the data are commercially sensitive.

We were able, however, to obtain confidential data on a sufficiently rich data set to evaluate the efficiency of maintenance service contracts at City West Water and Yarra Valley Water using the following general linear regression model:

$$EXPEND_t = \beta_0 + \beta_1 CUSTOMER_t + \beta_2 SMAIN_t + \beta_3 WMAIN_t + \beta_4 EXPEND_{t-1} + \beta_5 COMPANY_t + \beta_6 CONTRACTOR_t + \beta_7 CONTRACT_t + \beta_8 TIME + \sum_{i=1}^{11} \beta_{8+i} MONTH_{ti} + e_t \quad (9)$$

where $EXPEND_t$ is the total contract expenditure in month t;
$CUSTOMER_t$ is the number of retail customers in month t;
$SMAIN_t$ is the number of kilometres of sewer main in month t;
$WMAIN_t$ is the number of kilometres of water main in month t;
$EXPEND_{t-1}$ is the total contract expenditure in month $t-1$;
$COMPANY_t$ is a dummy variable for the retailers (=0 if YVW; =1 if CWW);
$CONTRACTOR_t$ is a dummy variable for the service providers (=0 if Company A; =1 if Company B);
$CONTRACT_t$ is a dummy variable for contract type (=0 if FP; =1 if C+);
$TIME$ is the time trend;
$MONTH_{ti}$ are dummy variables for months (M_{t1}=1 if month 1; =0 otherwise)
e_t is the error term in month t.

Data were collected on the independent and explanatory variables from three sources: water retailers, service providers and the regulator for the period September 1993 to October 2000 (a total of 86 monthly observations). The dependent variable $EXPEND_t$ was calculated in differing ways, depending on whether the contract was fixed-price or cost-plus. For a cost-plus contract, the service provider charges the retailer an hourly rate for work performed, regardless of the type of maintenance activity. $EXPEND_t$ in any given month t, therefore, is simply the sum of the number of hours worked multiplied by the charge per hour. Materials costs are passed through to the retailer at cost, so the charge per hour included here is simply a labour charge.

For a fixed-price contract, the price for each type of maintenance work (e.g. burst water mains) is fixed. Thus, the total amount spent on burst water mains in any given month is the number of burst water mains multiplied by the price. In some cases, the price used was a weighted average price since many of the activity categories had multiple prices. For example, fixing a burst water main less than 2 metres underground has a different price from fixing a burst water main which is greater than 2 metres underground. In order to get a single price, a weighted average was calculated using the expected distribution of activities provided in the request for tender documentation. Total contract expenditure ($EXPEND_t$) in any given month t for a fixed-price contract, therefore, is simply the sum of the amounts expended on each of the different maintenance activity categories.

In the data set used here, only a sample of the total maintenance activities provided is considered. Specifically, the following maintenance activity categories are included in the variable $EXPEND_t$: domestic service repairs, sewer blockages, tee insertions, sewer digouts, tappings, stop taps, and burst water mains. Each of these activities relates to a specific task performed by the contract service providers. Some of the activities are self-explanatory (burst water mains, sewer blockages), but others are more technical and necessitate some explanation. A tee piece, for example, is a water main fitting that is inserted into the main (generally at right angles) in order to divert the water main in a new direction. A stop tap is water main fitting that enables the supply of water to an individual property to be isolated from the main, so that maintenance work can be performed. Tappings relate to opening the water main under pressure in order to connect a new water service to the main.

Other activities included in the maintenance service contracts were not included in the analysis because of problems with of data availability and comparability. Firstly, data in the first contract period (1993-1996) were particularly poor – although the contracts provided great detail about the different activities performed, little was done to collate data on the work actually done by the service providers. Thus, for many of the activity categories, there is missing data on the activity levels performed, and thus expenditure cannot be determined.[6] Many maintenance activity categories were excluded from the analysis on this basis.

Secondly, there was a problem with comparability of data across the water retailers. Prior to 1993, the maintenance activities were coordinated within one statutory organisation

[6] This is a common problem in attempting to analyse expenditures pre- and post-outsourcing, particularly for government entities – wholly-owned government entities often didn't keep detailed data on services performed.

and were therefore standardised. Following the disaggregation of this organisation in 1993, each of the new retailers developed its own system of contract performance monitoring that affected the collection of data on maintenance activity levels. Part of this was due to the fact that City West Water moved to using a cost-plus contract in the second contract period, while Yarra Valley Water stayed with a fixed-price contract. As a result, the collection of data on maintenance activities was no longer standardised: Yarra Valley Water collected data on activities that did not appear on the City West Water's activity data. Therefore, activities were included in the analysis only if comparable data could be collected from both water retailers over time.

The descriptive statistics on the expenditure levels for the maintenance activities included in the empirical analysis are presented in Table 2 and Table 3. The average monthly expenditure on the selected bundle of maintenance services at City West Water is $365,032, while at Yarra Valley Water it is $452,654. The largest component of maintenance services expenditure at both water retailers is burst water mains, which accounts for an average monthly expenditure of $178,704 at City West Water and $189,325 at Yarra Valley Water. The next most important activity in terms of total expenditure is sewer blockages, which accounts for $43,828 and $80,143 at City West Water and Yarra Valley Water respectively. In total, the bundle of maintenance activities included in the analysis here accounts for approximately 60-70 per cent of the total contract value. Thus, the bundle of maintenance service activities included here accounts for a large proportion of the total contract value and there are no reasons to assume that excluding the other activities introduces any systematic bias.

Data on other explanatory variables were collected from the regulator and are also presented in Tables 2 and 3. $CUSTOMER_t$ is the number of water and sewerage customers in the retailers' catchment area. $SMAIN_t$ is the length of sewer mains (in kilometres) maintained by the service provider, while $WMAIN_t$ is the length of water mains maintained (in kilometres). Although there is little variation in these variables from month to month, they have been included here to control for the fact that the assets maintained by City West Water and Yarra Valley Water differ in size.

Table 2 Descriptive Statistics for City West Water

	N	Mean	Std.	Skewness	
	Statistic	Statistic	Statistic	Statistic	Std. Error
CUSTOMER	86	231673.4	19435.7	.088	.260
SMAIN	86	3324.5	147.3	.616	.260
WMAIN	86	2945.0	73.1	1.433	.260
EXPEND	85	365032.1	79344.9	.844	.261
- domestic services expenditure	85	43697.2	19387.3	.309	.261
- sewer blockage expenditure	85	43828.4	10994.3	.581	.261
- tee insertions expenditure	85	16604.0	9378.6	1.916	.261
- sewer digouts expenditure	85	35695.1	12027.3	.425	.261
- tappings expenditure	85	32954.7	12154.6	.518	.261
- stop taps expenditure	85	13548.7	3251.9	.205	.261
- burst water mains expenditure	85	178704.0	74061.0	1.557	.261
Valid N (listwise)	82				

Table 3 Descriptive Statistics for Yarra Valley Water

	N	Mean	Std.	Skewness	
	Statistic	Statistic	Statistic	Statistic	Std. Error
CUSTOMER	86	550253.4	21891.4	.523	.260
SMAIN	86	8301.8	100.9	.824	.260
WMAIN	86	7716.0	151.0	.866	.260
EXPEND	86	452653.9	105914.2	1.908	.260
- domestic services expenditure	86	58095.5	13930.3	.581	.260
- sewer blockages expenditure	86	80142.8	23519.0	.852	.260
- tee insertions expenditure	86	13962.1	9958.3	1.487	.260
- sewer digouts expenditure	86	35635.7	22653.7	2.047	.260
- tappings expenditure	86	45399.7	9426.7	.559	.260
- stop taps expenditure	86	30093.2	11684.9	.572	.260
- burst water mains expenditure	86	189324.8	100404.6	2.455	.260
Valid N (listwise)	86				

There are a number of interesting points to note about the descriptive statistics. The first is the significant difference in the size of the networks maintained by City West Water and Yarra Valley Water. City West Water maintains a network of assets that includes an average of 231,673 customers, with 3,325 kilometres of sewer mains and 2,945 kilometres of water mains (covering an area of 580 square kilometres). Yarra Valley Water, on the other hand, maintains a much larger network of assets: an average of 550,253 customers, with 8,302 kilometres of sewer mains and 7,716 kilometres of water mains (covering an area of 4034 square kilometres). Thus, the density of the network of assets maintained by City West Water (399 customers per square kilometre) is much higher than the density of Yarra Valley Water's network (136 customers per square kilometre). The reason for this difference is that City West Water maintains the water and sewerage infrastructure assets in the CBD region, whereas Yarra Valley Water maintains the water and sewerage assets in the outer suburbs of Melbourne.

The second point to note about the descriptive statistics is that the difference in total expenditure between the two retailers is not as large as expected given the difference in the network sizes. There are two factors that may explain this. Firstly, the unit cost of maintaining infrastructure is much higher at City West Water because they are responsible for maintaining the assets in the CBD and inner city areas. Water and sewerage assets are more expensive to repair in these areas because they are typically located under roads and buildings, and repairing them involves spending considerable resources to locate the problem[7]. Secondly, water and sewerage mains in the City West Water's catchment area may have a higher propensity to fail because of the age and condition of the assets. This is a function of the fact that City West Water maintains the infrastructure in the older parts of the city, where many of the assets are more than 50 years old.

4. Results and Analysis

Table 4 shows the results from different regressions based on the model and data outlined above for City West Water and Yarra Valley Water. The explanatory variables used in the regression analysis are presented in the first column of the table. The regression results presented in the second column relate to the general model presented above where total contract expenditure ($EXPEND_t$) is the dependent variable. The remaining regressions are used to determine whether the results observed are consistent across the range of maintenance activities performed. Where relevant, outliers have also been included as explanatory variables in the regression equations.

[7] There are also the negative externalities associated with increased traffic congestion associated with maintenance work performed in the central business district, but these are unpriced.

Looking at the results from the first regression, a couple of points stand out. The first is that the length of water main maintained (*WMAIN*) has a large negative and statistically significant effect on total contract expenditure – the coefficient on this variable is -199.4. In general, one would expect that the length of water and sewerage mains maintained would be positively correlated to expenditure, ceteris paribus. The result obtained here may reflect the fact noted earlier that although City West Water maintains a smaller network than does Yarra Valley Water, it is responsible for the Melbourne CBD area which has a much higher unit maintenance cost[8]. The results also indicate that expenditure in the previous month is a strong predictor of current expenditure which accords with a priori expectations since weather cycles that affect reactive maintenance activities tend to prevail for longer than one month. The coefficient on lagged expenditure is 0.54, which is significant at the 1 per cent level.

For the present purpose, the most interesting results relate to the signs of the coefficients on the variables *COMPANY*, *CONTRACTOR* and *CONTRACT*, since it is these results which indicate which of the service providers is cheaper and which of the contract types is more efficient. Looking at Table 4, the coefficient on the explanatory variable *COMPANY* is -537,985, which indicates that expenditure is lower at City West Water. In addition, the variable *CONTRACTOR* is negative and statistically significant at the 10 per cent level. This suggests that Company B is the cheaper of the two service providers: on average, they are $25,989 cheaper than Company A in any given month. Furthermore, the results indicate that use of a cost-plus contract has a positive and statistically significant effect on total contract expenditure. Controlling for other factors, implementation of a cost-plus contract increases total contract expenditure by $116,122 per month. This result indicates that the incentive effect dominates the risk premium effect, which confirms the McAfee and McMillan (1986) result that complete insurance is sub-optimal due to the effects of the moral hazard problem.

[8] The negative coefficient may also be due to multi-collinearity since the variables *SMAIN* and *WMAIN* are highly correlated with *COMPANY*. In addition to generating spurious relationships, multi-collinearity is often associated with high R^2 values and insignificant *t*-ratios (see Gujarati 1988). This latter problem does not appear to be an issue here since most of the coefficients are statistically different from zero. Potential remedies for the multi-collinearity problem – such as dropping one of the collinear variables – were tried and did not change the overall results of the model.

Table4 General Linear Regression Results on Expenditure

	Dependent Variables							
Explanatory Variables	**Contract Expenditure (*EXPEND*$_t$)**	**Domestic Services Expenditure**	**Sewer Blockage Expenditure**	**Tee Insertions Expenditure**	**Sewer Digouts Expenditure**	**Tappings Expenditure**	**Stop Taps Expenditure**	**Burst Water Mains Expenditure**
TIME	1406* (1.77)	202.9* (1.73)	46.7 (0.41)	247.1* (2.22)	122.6 (0.71)	-220.63* (-2.55)	-55.92 (-1.12)	764.1 (1.34)
CUSTOMER	-2.37 (-1.45)	-0.52** (-3.25)	-0.03 (-0.10)	0.03 (0.12)	0.61* (1.72)	-0.33* (-1.99)	0.12 (1.18)	-1.42 (-1.19)
SMAIN	160.1 (0.96)		5.38 (0.22)	-2.64 (-0.12)	-161.79** (-4.23)	36.91* (2.12)	2.39 (0.23)	252.6* (2.06)
WMAIN	-199.4* (-1.86)	32.93* (2.02)		-21.89 (-1.49)	4.05 (0.17)	41.23** (3.49)	-7.44 (-1.11)	-250.2** (-3.20)
$EXPEND_{t-1}$	0.54** (9.16)	0.55** (8.63)	0.72** (12.75)	0.58** (8.75)	0.25** (3.81)	0.27** (3.60)	0.18* (2.22)	0.55** (11.31)
Outlier 1	271592** (4.84)	33587** (3.84)	53753** (6.04)		77363** (6.34)		-25011** (-6.88)	209544** (5.19)
Outlier 2	242362** (4.35)	37359** (4.21)	38230** (4.31)		81600** (6.13)			309908** (7.66)
Outlier 3								185802** (4.69)
Outlier 4								181515** (4.52)
M_{t1}	40372** (3.00)	7853** (3.71)	-1860 (-0.86)	-322 (-0.18)	-6492* (-2.21)	-9720** (-6.94)	2420** (2.77)	24589* (2.37)
M_{t2}	19391 (1.39)	3216 (1.42)	-5428* (-2.51)	1487 (0.82)	-1056 (-0.35)	4366** (2.74)	1946* (2.27)	11232 (1.11)
M_{t3}	52220** (3.78)	6761** (3.07)	5032* (2.28)	294 (0.16)	-4033 (-1.36)	5215** (3.75)	1037 (1.20)	44738** (4.46)

M_{t4}	-34934*	-7156**	595	-1692	-1531	-3477*	-2389**	-13795
	(-2.44)	(-3.17)	(0.28)	(-0.93)	(-0.51)	(-2.37)	(-2.79)	(-1.34)
M_{t5}	18433	1537	4677*	2907	2047	5553**	1394	14624
	(1.30)	(0.69)	(2.09)	(1.58)	(0.68)	(3.94)	(1.60)	(1.49)
M_{t6}	-41802**	-8819**	-1771	-3007	-5254*	-356	-2694**	-19953*
	(-2.99)	(-4.05)	(-0.80)	(-1.62)	(-1.69)	(-0.24)	(-1.47)	(-2.01)
M_{t7}	17709	409	3832*	2046	593	1147	-1347	4757
	(1.26)	(0.19)	(1.73)	(1.08)	(0.19)	(0.79)	(-1.47)	(0.47)
M_{t8}	-16638	96	4651*	-106	4845	-481	442	-25355*
	(-1.18)	(0.04)	(2.01)	(-0.06)	(1.55)	(-0.33)	(0.48)	(-2.51)
M_{t9}	-26199*	-4353*	3099	-1513	9721**	-160	-973	-30898**
	(-1.79)	(-2.02)	(1.41)	(-0.77)	(3.04)	(-0.11)	(-1.07)	(-2.94)
M_{t10}	-22599*	567	-1957	1515	5178*	470	2055*	-26030**
	(-1.72)	(0.28)	(-0.95)	(0.88)	(1.82)	(0.36)	(2.56)	(-2.70)
M_{t11}	-30227*	-1030	-5905**	673	-2564	896	1225	-15856
	(-2.15)	(-0.48)	(-2.77)	(0.37)	(-0.86)	(0.64)	(1.43)	(-1.53)
COMPANY	-537985*	-8970	2649	-51376	-275658**	134131**	4599	-267458
	(-2.22)	(-0.26)	(0.08)	(-1.52)	(-5.03)	(4.66)	(0.30)	(-1.54)
CONTRACTOR	-25989*	-1810	-1777	4317**	-6923**	-1707	9420**	-10939
	(-2.17)	(-1.04)	(-1.16)	(2.70)	(-2.60)	(-1.48)	(7.83)	(-1.23)
CONTRACT	58061*	10809**	3062	-9060*	-1253	-843	-11429**	40713*
	(2.30)	(3.46)	(0.81)	(-2.57)	(-0.23)	(-0.34)	(-5.91)	(2.16)
Adj. R^2	0.74	0.79	0.90	0.48	0.60	0.80	0.92	0.82

Notes: *t*-statistics are presented in brackets. The symbols * and ** denote statistical significance at the 10% and 1% levels respectively.

The result obtained here that the incentive effect dominates the risk premium effect is in line with a priori expectations since maintenance services seem to be susceptible to moral hazard. There are two ways in which moral hazard can manifest in a cost-plus contract: either by increasing the number of hours taken to do each job (i.e. shirking) or by influencing the number of maintenance activities performed. The former may occur because effort is not easily observable and, in the presence of cost uncertainty, the purchaser will not be able to differentiate between shirking and a complex job. The latter is harder to envisage because the contractor has no direct influence over the number of jobs performed: they are simply directed by the purchaser. However, it is possible that the contractor could indirectly influence the number of jobs through quality shading – lowering the quality of work may fix the burst water main temporarily, but lead to another burst in the near future. As discussed earlier, we are not able to directly control for this effect here because of problems in determining "quality" in this environment.

City West Water was aware that using a fixed-price contract may induce moral hazard and instituted a contractual device aimed at attenuating the problem. Specifically, the cost-plus contract used at City West Water included an incentive mechanism in the form of a "profit at risk" component. The way this incentive mechanism works is that the contractor is provided with target unit costs for a bundle of different maintenance activities. If the contractor achieves the target unit cost, then City West Water pays them a pre-determined proportion of their profit.[9] This mechanism is similar to the cost-share parameter of incentive contracts since it provides a pecuniary incentive for the contractor to minimise worker shirking. The results obtained here suggest that this contractual mechanism has been unsuccessful in this case at mitigating the moral hazard effect.

[9] During the tendering process, each tenderer nominated their expected profit levels and how much of their profit they were prepared to put "at risk". In this instance, Company B nominated 100 per cent of its profit, which suggests confidence about their ability to achieve the target unit costs. However, there is no way of knowing whether the amount put "at risk" is in fact the total profit since actual costs are not observable. It is possible that only a portion of Company B's profit was identified in the tender. This is entirely plausible since contractors have an incentive to underestimate the level of profit earned because of its political sensitivity.

There are also some regulatory issues that were expected to reduce the size of the moral hazard effect. For example, each of the water retailers is granted an operating license by the government that contains a number of Key Performance Indicators (KPIs) that the retailer must achieve. Many of these KPIs form part of the contractual relationship between the retailers and the contractors. One such KPI is that 95 per cent of all unplanned water interruptions and sewer spills must be restored within 5 hours. Thus, contractors are provided an incentive to minimise the time taken to perform maintenance activities and to invest in monitoring the effort of workers' on-the-job performance. Imposing this type of yardstick competition attenuates the moral-hazard effect since it penalises cost-padding behaviour. However, the results presented here cast some doubt over whether this mechanism is high-powered enough to overcome the moral hazard effect.

Table 4 also provides information on the regressions undertaken on the different maintenance activities performed. Analysis of these results enables us to determine whether the finding that the cost-plus contract is more expensive than the fixed-price contract is consistent across the range of maintenance activities. Looking at the coefficients of the *CONTRACT* variable across the different activities indicates that it is statistically significant for four of the seven activities: domestic services, tee insertions, stop taps and burst water mains. However, the coefficient signs vary – for both domestic services and burst water mains the coefficient is positive, while for stop taps and tee insertions the coefficient is negative. Thus, the result that the incentive effect dominates the risk premium effect is not uniform across the bundle of maintenance activities included in this analysis. This is worthy of further investigation because if the characteristics of a maintenance activity that induce moral hazard can be identified, then measures can be introduced to provide a remedy.

One unobserved variable that may explain the lack of uniformity in the moral hazard effect across the maintenance activities is the firm's bidding behaviour. It is well-known in the literature on contracting and competitive bidding that firms often put in unbalanced (or skewed) bids as a means of hedging against the cash flow risk involved in unit-price contracts (see Burnett and Wampler 1998 and Ewerhart and Fieseler 2003, for example). Such a strategy may result in bid prices that are below average expected costs for some activities, while other activities seem over-priced. Under certain conditions, this non-monotonic bidding strategy may increase the probability of winning the contract while maintaining the rate of return.

While not able to control for this effect in the model, there is some anecdotal evidence to support the notion that strategic bidding occurred in the contracts considered here. Consider the bid prices at Yarra Valley Water for the activity sewer digouts for example, in the first contract period (1993-1996). Company B's fixed unit-price for the activity was $768.14. In the next round of contract bidding, Company B was unsuccessful in their bid and the contract was awarded to Company A. However, Company A's bid for that particular activity was $2,064.74. The fact that there is such a large discrepancy between the two bid prices suggests that either one of the contractors simply got their prices wrong, or that there was some strategic bidding in evidence. Unfortunately, we are not able to directly account for this factor in this model[10].

As already mentioned, the moral hazard effect observed in the results on cost-plus contract expenditure may have occurred through two mechanisms: cost-padding (increasing the number of hours taken to finish a job) or through quality-shading, whereby lowering the quality of work may result in more maintenance jobs in the future. Table 5 presents regression results that help determine which of these two explanations is driving the observed moral hazard effect. The regressions presented here are similar to those presented in Table 4 in that the same explanatory variables are used. The major difference is that the regressions presented in Table 5 use number of maintenance activities (rather than expenditure) as the dependent variable. In this regard, the regressions are designed to determine whether the type of contract used has a statistically significant effect on the number of maintenance activities performed by the contractor.

[10] The reason bidding behavior cannot be considered here is that we do not have access to the data on the bids submitted by each of the tenderers. All we had access to were the unit-prices submitted by the winning bidder.

Table 5 General Linear Regression Results on Number of Maintenance Activities

	Dependent Variable						
Explanatory Variables	**Domestic Services Activities**	**Sewer Blockage Activities**	**Tee Insertions Activities**	**Sewer Digouts Activities**	**Tappings Activities**	**Stop Taps Activities**	**Burst Water Mains Activities**
TIME	0.83* (1.78)	0.69 (1.27)	0.20* (2.33)	0.09 (0.95)	-0.85 (-1.33)	-1.09 (-1.12)	1.02 (1.05)
CUSTOMER	-0.002** (-3.42)	0.00	0.00	0.00	0.00	0.00	0.00
SMAIN		0.01 (0.13)	0.01 (0.37)	-0.07** (-3.27)	-0.04 (-0.29)	0.22 (1.07)	0.44* (-0.94)
WMAIN	0.09 (1.43)		-0.01 (-1.16)	0.02 (1.33)	0.41** (3.82)	-0.10 (-0.80)	-0.47** (-3.43)
$ACTIVITY_{t-1}$	0.57** (9.78)	0.78** (15.09)	0.48** (8.36)	0.24** (3.43)	0.46** (6.13)	0.14* (1.70)	0.57** (11.07)
Outlier 1	182.35** (5.19)	237.00** (5.73)	27.09** (4.59)	38.42** (5.75)			345.01** (5.02)
Outlier 2	205.61** (5.75)	180.36** (4.37)	33.06** (5.58)	37.28** (5.14)			488.32** (7.09)
Outlier 3			31.21** (5.00)				300.78** (4.40)
M_{t1}	38.51** (4.54)	-5.02 (-0.50)	0.18 (0.13)	-3.04* (-1.88)	-71.48** (-6.69)	38.46* (2.25)	35.31* (2.00)
M_{t2}	8.34 (0.91)	-29.12** (-2.90)	0.55 (0.37)	-1.37 (-0.84)	40.26** (3.34)	50.80** (3.04)	24.02 (1.39)
M_{t3}	26.45** (2.98)	29.57** (2.86)	0.58 (0.41)	-0.55 (-0.34)	32.33** (3.02)	24.69 (1.44)	67.63** (3.94)

M_{t4}	-38.38** (-4.24)	7.67 (0.77)	-2.62* (-1.78)	0.47 (0.29)	-31.01** (-2.79)	-42.34* (-2.51)	-27.57 (-1.57)
M_{t5}	2.66 (0.30)	29.59** (2.86)	1.56 (1.04)	0.67 (0.41)	49.83** (4.59)	25.37 (1.49)	11.76 (0.70)
M_{t6}	-39.17** (-4.50)	-8.18 (-0.80)	-1.68 (-1.16)	-4.02* (-2.36)	-5.96 (-0.52	-54.78** (-3.23)	-34.59* (-2.05)
M_{t7}	0.50 (0.06)	25.28* (2.45)	1.07 (0.72)	2.76 (1.57)	19.78* (1.77)	-30.53* (-1.69)	-0.55 (-0.03)
M_{t8}	-2.23 (-0.25)	18.26* (1.69)	0.45 (0.30)	1.51 (0.87)	-5.75 (-0.51)	-7.52 (-0.43)	-34.49* (-2.01)
M_{t9}	-7.62 (-0.87)	4.61 (0.45)	-0.76 (-0.50)	4.90** (2.78)	-6.53 (-0.56)	-21.64 (-1.21)	-53.80** (-3.01)
M_{t10}	6.84 (0.83)	-18.70* (-1.96)	1.91 (1.43)	2.60* (1.66)	-4.07 (-0.40)	46.76** (2.97)	-36.08* (-2.19)
M_{t11}	-5.09 (-0.59)	-33.50** (-3.39)	0.78 (0.55)	-1.84 (-1.13)	-5.14 (-0.48)	29.11* (1.72)	-26.26 (-1.50)
COMPANY	-163.7 (-1.21)	-76.7 (-0.51)	-26.29 (-0.98)	-106.51** (-3.56)	645.3** (2.96)	383.90 (1.32)	-465.2 (-1.55)
CONTRACTOR	-20.18** (-2.82)	-0.64 (-0.09)	3.16* (2.36)	3.90** (2.80)	-22.85* (-2.49)	37.86** (2.65)	-9.87 (-0.66)
CONTRACT	53.07** (4.18)	19.60 (1.12)	-5.84* (-2.01)	-5.07* (-1.72)	74.16** (3.56)	-33.60 (-1.13)	71.50* (2.19)
Adj. R^2	0.85	0.90	0.67	0.69	0.78	0.90	0.81

Notes: *t*-statistics are presented in brackets. The symbols * and ** denote statistical significance at the 10% and 1% levels respectively

The key result presented in Table 5 relates to the coefficient on the variable *CONTRACT* for the activities domestic service repairs and burst water mains. Expenditure on these two activities was found to be positively related to the use of a cost-plus contract. Looking at Table 5, it can be seen that this result is being driven by the fact that the number of activities is positively related to the use of a cost-plus contract – the coefficient on domestic services is positive and highly statistically significant, while the coefficient for burst water mains is positive and significant. This indicates that use of a cost-plus contract resulted in an additional 53.07 domestic service activities per month, and 71.50 burst water mains per month. Thus, it appears that the contractor may be able to influence the number of activities performed, possibly through quality shading.

While there may be some evidence to suggest quality shading here, this is very difficult to substantiate because of the problems of measuring quality in a maintenance services environment. In particular, it is not possible to differentiate between a maintenance failure that occurs through natural wear and tear, or because of poor quality workmanship. It is also possible that other factors have caused the observed correlation between number of maintenance activities and contract type. For example, City West Water introduced a new asset management philosophy in the late 1990s which may have had some effect on the incidence of reactive maintenance activities. In an audit of asset management practices conducted by the Essential Services Commission (2002), it was reported that:

> City West Water reduced its renewal expenditure for 2000/01 to about half the allocated budget, which is also significantly below historical levels of expenditure…More time is needed for City West Water to fully demonstrate the sustainability of its new approach and its ability to continue to respond to different climatic conditions… (p.79).

Although the report concludes that there has been no observable deterioration in asset performance, it cannot be ruled out that City West Water's asset management practices have also played a part in the observed increase in reactive maintenance activity levels since expenditure on asset renewal/refurbishment and other preventative maintenance activities has a significant effect on reactive maintenance levels.

5. Conclusions

According to standard contract theory, the efficiency of cost-sharing arrangements is increasing in the uncertainty of the environment. The reason is that as the level of uncertainty increases, so does the size of the risk premium charged by a risk-averse agent. At some point, the risk premium effect outweighs the moral-hazard effect associated with insuring the agent. This theoretical framework has typically been used to analyse procurement of a single, indivisible good in the presence of cost uncertainty. In this article, it is argued that the standard model must be extended if the contracting problem involves service procurement since service provision is often affected by both cost and demand uncertainty. In this article, we develop a simple model for efficient service contracts to account for the complexity of common service environments.

To determine whether the standard risk-incentive trade-off results occurs in this more complex contractual environment, empirical analysis was undertaken using data collected from outsourcing contracts at two Melbourne water retailers. One of the features of these contracts is that two types of contracts have been used: fixed-price and cost-plus contracts. Using a general linear regression model that controls for differences in the size of the networks, the results indicate that the cost-plus contract is more expensive than the fixed-price contract. Useful extensions of the model developed in this article might consider whether firms include risk premia (or excess capacity) into their bidding strategies when dealing with services which are characterised by exogenous demand shocks.

References

Ackerberg, D.A. and M. Botticini. 2002. "Endogenous matching and the empirical determinants of contract form", *Journal of Political Economy* 110(3), 564-591.

Aggarwal, R. and A. Samwick. 1999. "The other side of the tradeoff: the impact of risk on executive compensation", *Journal of Political Economy* 107, 65-105.

Allen, D.W. and D. Lueck. 1992. "Contract choice in modern agriculture: crop-share versus cash rent", *Journal of Law and Economics* 35, 397-426.

Allen, D.W. and D. Lueck. 1999. “The role of risk in contract choice”, *Journal of Law, Economics and Organization* 15(3), 704-736.

Andersen, E. and D.C. Schmittlein. 1984. “Integration of the sales force: an empirical examination”, *RAND Journal of Economics* 15, 385-395.

Bajari, P. and S. Tadelis. 2001. “Incentives versus transaction costs: a theory of procurement contracts”, *RAND Journal of Economics* 32(3), 387-407.

Banerjee, A. and E. Duflo. 2000. “Reputation effects and the limits of contracting: a study of the Indian software industry”, *Quarterly Journal of Economics* 115, 989-1017.

Benabou, R. and J. Tirole. 2003. “Intrinsic and extrinsic motivation”, *Review of Economic Studies* 70(3), 489-520.

Brickley, J.A., Dark, F.H. and M.S. Weisbach. 1991. “An agency perspective on franchising”, *Financial Management* 20, 27-35.

Burnett, J.E. and B.M. Wampler. 1998. “Unit price contracts: a practical framework for determining competitive bid prices”, *Journal of Applied Business Research* 14(3), 63-72.

Chiappori, P.A. and B. Salanie. 2000. “Testing contract theory: a survey of some recent work”, Invited Lecture, World Congress of the Econometric Society, Seattle, August.

Corts, K.S. and J. Singh. 2004. “The effect of repeated interaction on contract choice: evidence from offshore drilling”, *Journal of Law, Economics and Organization* 20(1), 230-260.

Crocker, K.J. and K.J. Reynolds. 1993. “The efficiency of incomplete contracts: an empirical analysis of air force engine procurement”, *RAND Journal of Economics* 24(1), 126-146.

Essential Services Commission (2002), *Melbourne’s Retail Water & Sewerage Companies Performance Report*, 2000-2001.

Ewerhart, C. and K. Fieseler. 2003. “Procurement auctions and unit-price contracts”, *RAND Journal of Economics* 34(3), 569-581.

Frey, B.S. and R. Jegen. 2001. “Motivation crowding theory”, *Journal of Economic Surveys* 15(5), 589-611.

Gujarati, D.N. 1988. *Basic Econometrics*. McGraw-Hill Book Company: New York.

Hart, O., Shleifer, A. and R.W. Vishny. 1997. “The proper scope of government: theory and an application to prisons”, *Quarterly Journal of Economics* 112, 1127-1161.

Holmström, B. 1979. “Moral hazard and observability”, *Bell Journal of Economics* 10, 74-91.

Holmström, B. and P. Milgrom. 1991. “Multitask principal-agent analyses: incentive contracts, asset ownership, and job design”, *Journal of Law, Economics and Organization* 7(Special), 24-52.

John, G. and B. Weitz. 1989. “Salesforce compensation: an empirical investigation of factors related to the use of salary versus incentive compensation”, *Journal of Marketing Research* 26, 1-14.

Lafontaine, F. 1992. “Agency theory and franchising: some empirical results”, *RAND Journal of Economics* 23, 263-283.

Lafontaine, F. and M.E. Slade. 2001. “Incentive contracting and the franchise decision”, In Chatterjee, K. and W.F. Samuelson (eds.), *Game Theory and Business Applications*. Kluwer Academic: Boston.

Lazear, E.P. 2000. “Performance pay and productivity”, *American Economic Review* 90(5), 1346-1361.

McAfee, R.P. and J. McMillan. 1986. “Bidding for contracts: a principal-agent analysis”, *RAND Journal of Economics* 17(3), 326-338.

Murdock, K. 2002. “Intrinsic motivation and optimal incentive contracts”, *RAND Journal of Economics* 33(4), 650-671.

Prendergast, C. 1999. “The provision of incentives in firms”, *Journal of Economic Literature* 37(March), 7-63.

Prendergast, C. 2002. “The tenuous tradeoff between risk and incentives”, *Journal of Political Economy* 110(5), 1071-1102.