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Dynamic costs and moral hazard: A duality-based approach ☆

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Abstract

The marginal cost of effort often increases as effort is exerted. In a dynamic moral hazard setting, dynamically increasing costs create information asymmetry. This paper characterizes the optimal contract and helps explain the popular yet thus far puzzling use of non-linear incentives, for example, in sales-force compensation. The result is obtained by complementing the standard dynamic program with a novel dynamic dual formulation. The dual program is monotonic and sub-modular, providing stronger results, including a proof for the sufficiency of one-shot deviations.

JEL classification: C61; D82; D86

Keywords: Dynamic moral hazard; Nonlinear incentives; Private information; Dynamic mechanism design; Duality

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1. Introduction

Increasing marginal costs are a standard component of economic analysis. In organizational settings, the increase in cost often has a dynamic motivation. A worker picking fruits, for example, gets tired as the day progresses. A sales agent typically depletes the easier sales at the start of the quarter and must exert more effort to generate later sales.

Because effort is unobserved, increasing marginal costs generate a private-information problem. After a few periods, only the agent knows whether he has really worked. If the firm knew the agent's true cost, it would want to increase incentives as effort costs increase. However, the agent may have previously shirked, and his cost may still be low. As a result, adaptive policies decrease the agent's incentive to work early on as he prefers to save his effort for the higher rewards.

This paper characterizes the optimal mechanism for a dynamic moral hazard setting in which the cost increase depends on the agent's past, unobservable, effort. The agent starts in an evaluation stage and eventually moves to a compensation stage. In the compensation stage, the agent works for an additional *fixed* number of periods that is *independent* of any new outcomes. In the evaluation stage the agent is rewarded *only* by changes to the expected length of the compensation stage and the number of successes required to enter that stage. In the compensation stage, the payment per success increases in the costs in all remaining periods. If the agent does not discount future periods, he is paid as if all efforts in the compensation stage cost as much as the last effort. If the agent accumulates enough early successes, his pay-per-success later in the quarter will be high. If the agent did not accumulate enough early successes, the contract leads the agent to stop working.

The main departure from existing contracts is that the eventual compensation level here depends on the agent's early performance. The agent may receive a 5% commission in some realizations and a 15% commission in others. This is difficult to explain using the existing static or dynamic contracts,[1] yet is consistent with observed contracts, especially in sales.[2]

A growing literature, surveyed below, investigates whether and how inter-temporal agency issues (here, the increasing cost) restrict the optimal contract. The closest dynamic models without inter-temporal issues are DeMarzo and Fishman (2007) and Clementi and Hopenhayn (2006) in which the risk-neutral agent's period production is bounded from below, the agent can only divert or prevent some positive revenue. In such models, the contract initially rewards the agent only in changes to his continuation utility. If the continuation utility drops below a certain level, the agent is retired. If it reaches the first-best continuation surplus, the firm is "sold" to the agent and the continuation is fixed at the first-best level.

[1] Allowing for private information on the agent's side of his initial productivity can explain a menu of fixed-wage contracts from which the agent chooses at the outset. Here, as in the contracts discussed by Prendergast (1999), the single contract offers several commission levels.

[2] Misra and Nair (2011) document contracts for contact-lens sales agents that pay a commission per sale only if the agent made enough sales in the current quarter. Misra and Nair (2011) note that, according to industry observers, little or no seasonality exists in the underlying demand, and the salesperson has no control over prices. Their estimation confirms that an agent's effort is strongly affected by whether or not the agent expects to meet the threshold for the quarter. Larkin (2014) documents contracts for software sales agents that pay the a commission per sale that increases in the amount the agent sold so far in the quarter. In both papers, the same agent may receive a high commission rate in one quarter and a low (or no) commission in another, based on his results early in the quarter. Joseph and Kalwani (1998) document the extensive use of quota-based contracts in sales force compensation.