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# Price Delegation or Not? The Effect of Heterogeneous Sales Agents

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In this study, we examine the effect of the differences in both sales ability and reservation utility on the design of the pricing scheme and compensation contract under asymmetric information. Heterogeneity with ability-dependent reservation utility generates conflicted screening and pooling effects that preclude separating and pooling equilibria, respectively; with which agents may work harder under either centralized or delegated pricing scheme than if they were homogeneous and, in certain scenarios, no premiums (information rents) are paid. These findings are driven by the dynamics between the differences in agents' reservation utilities and in their effort costs or rewards that arise when their true types are concealed. We show that optimal separating contracts generate the same profit under centralized and delegated pricing because separating contracts under centralization retain the pricing flexibility of delegation. However, a certain form of pooling contract under delegated pricing can outperform the optimal pooling contract under centralization because the upside of pricing flexibility under delegation dominates the downside caused by reduced effort incentives. Under the optimal contracts, delegated pricing is as profitable to the firm as centralized pricing when the difference of reservation utilities is small or when the difference is large but the ability gap is small, and delegation is preferred when the difference of reservation utilities is moderate or when both the difference and the ability gap are large.

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## 1. Introduction

Delegation of pricing authority is a critical issue in organization design for firms that rely on agents to sell products and services. Varied degrees of price delegation are observed in different industries. Stephenson et al. (1979) surveyed medical supplies and equipment trading firms and discovered that sales personnel have no, limited, and full pricing authorities in 29%, 48%, and 23% of the sample, respectively. Similar findings are reported for financial services, pharmaceutical, consumer goods, industrial goods industries (Hansen et al. 2008), and industrial machinery and electrical engineering sectors (Frenzen et al. 2010). The amount of superior customer demand information that sales agents have and the form of compensation contract are suggested to be important factors that affect price delegation (Stephenson et al. 1979).

In an early study, Weinberg (1975) examined the effect of the form of compensation contract on delegation and suggested that price delegation benefits a firm and its agents when commissions for the latter are a percentage of the gross margin, rather than that of the sales revenue. Lal (1986) documented that delegation is more profitable for the firm than centralization if agents possess certain information that the firm does not know. Mishra and Prasad (2004) showed that centralization outperforms delegation when sales agents' private information about the stochastic part of demand can be revealed to the firm through their contract choice. Essentially, Lal (1986) and Mishra and Prasad (2004) found a determinant of price delegation: agents' private information unknown to the firm.

Using data from a survey of 201 firms, Lo et al. (2016) showed empirically that agents are given more pricing authority when they are more capable. Although information asymmetry is not an issue addressed in Lo et al. (2016), their finding suggests that agents' ability could also affect a firm's delegation decision. The extant principal-agent models of price delegation or compensation contracts have assumed a common (an identical) reservation utility among the members of a heterogeneous sales force, and thus, they perhaps could not reveal the possible roles played by agents' private ability information, although they answered questions on delegation and compensation contract well assuming the identical reservation utility (e.g., Lal 1986, Mishra and Prasad 2004, Rao 1990). However, agents with private information on selling abilities are more likely to have type-dependent reservation utilities, since a high-ability agent may have better outside options (opportunity costs) than a low-ability one and therefore requires a higher reservation utility (Fudenberg and Tirole 1991, Nagar 2002). It is unknown from the literature how differently firms make price delegation and agent compensation decisions when their heterogeneous agents have different reservation utilities.

We thus consider in this study the problem of joint price delegation decision and compensation contract design for a heterogeneous sales force. Reservation utility depends on the agent type for various reasons, such as different fixed trading or opportunity costs and/or different tolerances for risk, principals competing in the same market, and contract renegotiation (Armstrong and Sappington 2004, Cakanyildirim et al. 2012, Fudenberg and Tirole 1991, Gan et al. 2019, Jullien 2000, Laffont and Tirole 1990, Lewis and Sappington 1989). Here, we assume that agents differ in selling abilities, which are their private information, and a higher selling ability (type) requires a higher minimum compensation, that is a higher reservation utility. In our proposed principal-agent model, the firm is uninformed about the abilities and reservation utilities of its sales agents. But the firm is aware of the distribution of agent type and the relation between agent type and the corresponding reservation utility. We identify the conditions under which an optimal compensation contract exists under each of the two pricing schemes and then characterize the contracts. Examining the optimal compensation contract design, we find that heterogeneity in abilities and type-dependent reservation utilities has two effects on the firm's contract design: *conflicted screening* and *conflicted pooling* effects. Irrespective of the pricing scheme, no separating equilibrium contracts can exist when a conflicted screening effect is present, and no pooling equilibrium contract is possible when the conflicted pooling effect prevails.

In contrast to Mishra and Prasad (2004) where the heterogeneous agents have a common reservation utility, when agent's reservation utility depends on his ability, centralization is not always preferred by the firm given that the firm is free to design an optimal compensation plan. The heterogeneity of agents' abilities and type-dependent reservation utilities endogenously determines the available optimal compensation contracts and therefore drives the price delegation decision. When the difference of reservation utilities is small or when the difference is large but the ability gap is small, the conflicted screening effect does not appear under each pricing scheme, and delegation and centralization are indifferent to the firm with the optimal separating contracts. When the difference of reservation utilities is moderate or when both the difference and ability gap are large, the conflicted screening effect exists under centralized pricing, and the optimal contract of centralization is the pooling one. Under this scenario, we propose a certain form of contract referred to as margin-based commission contract (or MBC contract) for delegated pricing, and obtain the corresponding optimal separating and pooling MBC contracts. We prove that the optimal pooling MBC contract under delegation is more profitable than the optimal pooling contract under centralization. Therefore, for the firm, delegation, sometimes with separating MBC contracts and sometimes with a pooling MBC contract due to the conflicted screening effect, performs better than centralization with the optimal pooling contract. Under the type-dependent reservation utility, we also find that, with the optimal contracts, at least one agent type (either high or low) does not receive information rent and may work as hard as if all agents were homogeneous; furthermore, there are certain conditions under which all agents work as hard or even harder than if they were part of a homogeneous sales force. This finding is different from a prominent conclusion, for heterogeneous sales force with a common reservation utility, in the extant literature: all but the agent with the lowest ability receive an information rent and all but the agent with the highest ability expand less effort than if they were homogeneous (e.g., Rao 1990). In conclusion, taking the type-dependent reservation utility into account, heterogeneity in private to agents' ability affects the price delegation decision significantly and helps explain the varied use of price delegation and the unique contract in practice. Our results also show that firms can explore agents' heterogeneity in both ability and reservation utility and design the right combination of pricing scheme and compensation contract to make the heterogeneous sales force work effectively. Therefore, managers should assess the differences in agents' abilities and reservation utilities before choosing between centralized and delegated pricing. We extend our base model by considering uncertain demands, correlation across sales territories, and continuous type; and the main results of the base model remain qualitatively true under these variations.

The remainder of the study can be organized as follows. Section 2 presents the literature review. Section 3 defines the models for centralized and delegated pricing. Section 4 describes the contract menus for the two models and examines the firm's preference on delegation or centralization. Section 5 extends our base model. Section 6 concludes the study with a summarized discussion. All proofs are provided in an online supplement.

## 2. Literature Review

In an early work on sales agent price delegation, Weinberg (1975) stated that both the firm and the agent can benefit from price delegation when the marginal cost is constant and the commission is based on a percentage of the gross margin. Lal (1986) used an agency theory framework to show that price delegation is more profitable for the firm than price centralization when the salesperson possesses relevant private information that is unavailable to the firm. Joseph (2001) analyzed two factors that may affect the price delegation decision, namely, the endogenous sales behavior under price delegation and the amount of superior information that the sales agent possesses about a customer's willingness to pay; these factors are among the several ones that were suggested by Stephenson et al. (1979). Joseph (2001) found that if the sales effort cost of pursuing high-quality customers is either relatively low or relatively high, then full price delegation is optimal, whereas limited price delegation is optimal for the intermediate levels of such effort cost. Bhardwaj (2001) investigated how the competition in price and sales effort affects delegation decisions. He found that firms should delegate when the price competition is intense, but centralized pricing is preferable under high levels of sales effort competition.

Mishra and Prasad (2004, 2005) demonstrated that in monopolized and competitive settings, centralized pricing performs at least as well as delegated pricing (for the firm) if the sales agent's private information is revealed by his choice of contract. They also noted that the nature of the private information (i.e., about the agent's selling ability or market condition) may not affect the results stemming from the firm's price delegation decision with homogeneous reservation utility of agents. Nagar (2002) used survey data to empirically establish that lower-level managers who are given more pricing authority receive higher power incentive schemes, and managers with greater abilities receive more incentive compensation. Lo et al. (2016) showed that sales agents with greater abilities (i.e., experiences and skills) are granted more pricing authority. Simester and Zhang (2014) examined the "internal lobbying" phenomenon when sales representatives possess private information about demands, and they derived conditions under which the firm prefers such lobbying over price delegation. Lim and Ham (2014) conducted a laboratory economics experiment to examine the relationship between price delegation and managerial profits. Their experiment revealed that price delegation is more frequently selected when the firm awards a bonus to sales agents after observing their decisions. This study is different from the above mentioned works in that we consider the heterogeneity of sales agents in terms of both sales ability and reservation utility and show that type-dependent reservation utility has a significant effect on the firm's pricing delegation decision.

The literature on sales force compensation is extensive. Basu et al. (1985) considered a homogeneous and risk-averse sales force in the context involving moral hazard and proposed a nonlinear optimal compensation plan. However, Lal and Staelin (1986) discovered that the nonlinear compensation contract described by Basu et al. (1985) may not be optimal if the sales force is heterogeneous, and information asymmetry is present. Lal and Srinivasan (1993) discussed linear compensation plans for single- and multi-product sales forces. By assuming ex ante symmetric information, they demonstrated through comparative statics that the improvements in alternative job opportunities can increase salaries but cannot affect commission rates, which determine the sales effort. By contrast, our model features the type-dependent reservation utility that affects not only agents' payments but also their effort decisions. As previously mentioned, Rao (1990) proposed a menu of quota-based compensation plans for a heterogeneous sales force with identical reservation utility and private information on abilities. He further showed that only the lowest agent type does not receive information rent and only the highest one delivers the first best effort. Raju and Srinivasan (1996) described scenarios where the performance of quota-based contracts nearly matches that of Basu et al. (1985) optimal plan.

Park (1995) and Kim (1997) demonstrated that bonuses awarded for meeting the sales quota may induce the first best efforts of agents when binding participation constraints are present in a moral hazard problem. In a similar setting, Oyer (2000) demonstrated that a quota-based plan may result in the first best efforts of agents who do not face binding participation constraints. Kala and Shi (2001) and Murthy and Mantrala (2005) investigated the use of sales contests as a relative performance-based incentive scheme. In this study, we design a compensation contract for a heterogeneous sales force characterized by type-dependent reservation utility under different pricing schemes. We show that both high- and low-type agents can make the first best effort without rent under certain conditions.

Several scholars have considered different sales force incentive problems. Mantrala et al. (1994) studied the compensation of a heterogeneous sales force that sells multiple products. Joseph and Thevaranjan (1998) examined the roles played by monitoring and incentivizing sales agents in a compensation scheme. Misra et al. (2005) considered agents' risk attitudes in the firm's compensation of a heterogeneous sales force. Caldieraro and Coughlan (2009) showed how the interaction between territory allocation and sales force compensation affects the firm's profit. Chen (2000, 2005) explored sales force incentive problems in connection with inventory decisions. Chen and Xiao (2012) studied a three-layer supply chain, in which a manufacturer sells a product through a reseller, who then relies on its own sales agent to sell in the end market. Yang et al. (2013) examined the effect of emotions on the choice between sales contests and quotas when sales territories are imbalanced. Chu and Lai (2013) investigated sales force contracting when excess demands lead to lost sales, but the demand information is censored by the inventory level. Dai and Jerath (2013) considered the firm's joint decisions regarding inventory level and sales force contract design. Chen et al. (2016) compared forecast-based contracts with menus of linear contracts when sellers exert effort to acquire information on market conditions and increase demands. Rubel and Prasad (2016) proposed a dynamic model for the design of sales force compensation plans when the effect of the selling effort on sales in one period persists for several periods. In contrast to the existing research, we focus on the effect of type-dependent reservation utility on the pricing scheme selection and compensation contract design of a firm with a heterogeneous sales force.

Reservation utility of type dependence has been investigated in the economics literature, for example, Lewis and Sappington (1989), Maggi and Rodriguez-Clare (1995), Laffont and Tirole (1990), Jullien (2000), Armstrong and Sappington (2004). These works analyzed the properties of the optimal contract when the agent's reservation utility relates to the type. One of the characteristics of type-dependent reservation utility model is that the incentive compatibility (IC) and individual rationality (IR) constraints of all types can be binding differently. Recently, some works considered the type-dependent reservation utility in the operations management, such as Chakravarty and Zhang (2007), Cakanyildirim et al. (2012) and Gan et al. (2019). Our research develops the pricing scheme and compensation contract in the context of sales force management with type-dependent reservation utility, and provides insights into the scenario when heterogeneous sales agents are employed.

## 3. Model

The manager (she) of a firm that employs heterogeneous sales agents must decide whether or not to delegate the pricing decision to the agents and must also jointly design a set of compensation contracts for the agents to maximize the profit generated from each agent. Each agent (he) selects a contract, sets the price (if the pricing decision has been delegated to him), and exerts the level of sales effort that maximizes his own profit. The abilities (types) and reservation utilities of individual agents are unknown to the manager. The reservation utilities are type dependent: agents with greater ability have higher reservation utility. The manager knows the proportions (distributions) of the agent types, and she can estimate the different market responses generated by different agent types. She also knows the different reservation utilities from the prevailing industry standards. However, she cannot observe agents' sales efforts. This lack of observability dictates that the compensation scheme must be based on the realized sales. The manager may learn an agent's type by observing which contract he chooses. Thus, a contract stipulates the sales compensation and, under centralized pricing, the product price. We also assume that agents have mutually exclusive sales territories,[1] hence, neither competition among agents nor price substitution effect exists under delegated pricing.

The manager simultaneously decides on the pricing scheme and compensation contracts, and the sequence of events in the model is as follows: (i) The manager offers the pricing scheme (centralized or delegated) and a menu of contracts, including product price under centralized pricing, to a sales agent who has private information about his selling ability and reservation utility. (ii) The agent selects and signs a contract. (iii) The agent sets the price (under delegated pricing), determines his sales effort, and proceeds to sell the firm's product. (iv) Both parties observe the realized sales, and the manager pays the sales agent according to the terms of his contract.

We assume that the realized sales $s$ of the agent is a linear function of the price $p$, his type $\theta$, and his effort $e$, that is,

$$s = s_0 + \theta e - bp, \tag{1}$$

where $s_0$ is the market potential,[2] $b$ is the price elasticity, and $s_0$ and $b$ are positive. The specification of a tractable linear response function is reasonable for many market situations and is common in the literature (Bhardwaj 2001, Chen 2005).

For clarity, we restrict the discussion to two agent types:[3] high (H) and low (L) types with respective abilities $\theta_H$ and $\theta_L$, where $\theta_H > \theta_L > 0$. $R_i$ is used to represent the reservation utility of a type-$i$ agent, where $i = H$ or $L$ and $R_H \geq R_L > 0$. The sales force may comprise many individual agents, and each is either a high type or a low type. The proportions $\rho$ and $1 - \rho$ ($\rho \in (0, 1)$) of the high- and low-type agents in the job market, respectively, are common knowledge. We assume that $2b > \theta_H^2$ and $s_0$ is sufficiently large to ensure that for any $R_i$, the firm's profit is nonnegative.[4] These assumptions are common in the literature (Laffont and Tirole 1988).

Let $c(e)$ denote the *effort cost* or the cost of exerting effort level $e$. We assume that $c(e)$ increases with $e$, and at an increasing rate (Basu et al. 1985):

$$c(e) = e^2/2. \tag{2}$$

Let $\{t(q, \theta), p(\theta)\}$ be the contracts under centralized pricing, where $q$ is the sales quota, $t$ is the agents' compensation, and $p$ is the price. The contracts specify the product price and the amount that the firm will pay to the agent for meeting the quota. Given that the scheme allows the agent to choose the contract, we can restrict $\{t(q, \theta), p(\theta)\}$ to $\{t_H(q_H), p_H\}$ and $\{t_L(q_L), p_L\}$ for high- and low-type agents, respectively, by applying the revelation principle. In view of the deterministic response function given by Equation (1), the agent's selected quota can be achieved precisely. Thus, under such a quota-based contract, the agent is paid a fixed amount if the quota is reached and nothing if not.

Let $x$ denote the type of contract, where $x = H$ or $L$. The reward received by type-$i$ agent who selects the contract designed for type-$x$ agent is expressed as $V_i(e,x) = t_x(q_x) - c(e_{ix})$ ($i = H$ or $L$), where $e_{ix}$ is the effort that type-$i$ agent exerts to meet quota $q_x$. We normalize the unit product cost to zero (because the unit price is already net of the cost). If the agent selects the contract for his type, the firm's expected profit $\Pi_c$ from the agent is

$$\begin{aligned}\Pi_c(p_H, t_H(q_H), p_L, t_L(q_L)) &= \rho(p_H \times q_H - t_H(q_H)) \\ &\quad + (1-\rho)(p_L \times q_L - t_L(q_L))\end{aligned}$$

The resulting principal-agent problem that the firm will solve under centralized (**c**) pricing is then

$$\mathbf{P_c}: \max \Pi_c(p_H, t_H(q_H), p_L, t_L(q_L))$$

$$s.t.\ \begin{array}{ll} (I) & t_H(q_H) - c(e_{HH}) \geq R_H \\ (II) & t_L(q_L) - c(e_{LL}) \geq R_L \\ (III) & t_H(q_H) - c(e_{HH}) \geq t_L(q_L) - c(e_{HL}) \\ (IV) & t_L(q_L) - c(e_{LL}) \geq t_H(q_H) - c(e_{LH}) \\ (V) & e_{ix} = \dfrac{q_x + bp_x - s_0}{\theta_i}, \quad i,x = H \text{ or } L \end{array}. \tag{3}$$

In $\mathbf{P_c}$, constraints (I) and (II) are the individual rationality (IR) constraints to ensure that the agent's net income from the contract designed for his type is not less than his reservation utility. Constraints (III) and (IV) are the incentive compatibility (IC) constraints to ensure that high-type agent prefers contract $\{t_H(q_H), p_H\}$, whereas low-type agent prefers contract $\{t_L(q_L), p_L\}$. Constraint (V) reflects the nature of the deterministic demand function: the agent will exert the exact effort to realize the quota that he selects.

Under delegated pricing, the agent's compensation is expressed as $\{t(s, p(\theta), \theta)\}$, where $p$ is the product price set by the agent, and $s$ is the quantity of product sold by the agent. Under this scheme, the pair of contracts offered by the firm are $\{t_H(s, p)\}$ and $\{t_L(s, p)\}$. The reward $V_i(p, e, x)$ of type-$i$ agent after choosing type-$x$ contract is

$$V_i(p,e,x) = t_x(s_{ix}, p_{ix}) - c(e_{ix}), \quad i, \ x = H \text{ or } L. \tag{4}$$

If the agent selects the contract for his type, the firm's expected profit $\Pi_d$ under delegated pricing is

$$\begin{aligned}\Pi_d(t_H(s,p), t_L(s,p)) &= \rho(p_{HH} \times s_{HH} - t_H(s_{HH}, p_{HH})) \\ &\quad + (1-\rho)(p_{LL} \times s_{LL} - t_L(s_{LL}, p_{LL})).\end{aligned} \tag{5}$$

The resulting principal-agent problem to be solved by the firm under delegated (**d**) pricing is:

$$\mathbf{P_d}: \max \Pi_d(t_H(s,p), t_L(s,p))$$

$$s.t.\ \begin{array}{ll} (I) & t_H(s_{HH}, p_{HH}) - c(e_{HH}) \geq R_H \\ (II) & t_L(s_{LL}, p_{LL}) - c(e_{LL}) \geq R_L \\ (III) & t_H(s_{HH}, p_{HH}) - c(e_{HH}) \geq t_L(s_{HL}, p_{HL}) - c(e_{HL}) \\ (IV) & t_L(s_{LL}, p_{LL}) - c(e_{LL}) \geq t_H(s_{LH}, p_{LH}) - c(e_{LH}) \\ (V) & (p_{ix}, e_{ix}) = \text{argmax } t_x(s_{ix}, p_{ix}) - c(e_{ix}), \quad i,x = H \text{ or } L \end{array}. \tag{6}$$

Here, constraints (I) and (II) in $\mathbf{P_d}$ are the IR constraints, whereas constraints (III) and (IV) are the IC constraints. We stipulate these constraints to ensure that the agent selects the contract designed for his type to reveal his true type to the firm. Note that constraint (V) defines or specifies the agent's actions.

# 4. Main Results

## 4.1. Contracts under Centralized Pricing

In this section, we first derive the optimal separating contracts under centralized pricing. Apart from the ability to determine the payments to agents for realizing the quotas, the separating contracts have the self-selection feature. On the basis of the proposed deterministic demand function, according to Harris and Townsend (1981), the optimal scheme under centralized pricing can be described using contracts $\{t_H, q_H, p_H\}$ and $\{t_L, q_L, p_L\}$. Given that the optimal separating contracts are not always possible, we also examine the pooling contract (i.e., unique contract $\{t, q, p\}$). The comparison of the optimal separating and pooling contracts can establish an optimal strategy under centralization.

We use $r > 1$ to denote the ability ratio of the high-type to the low-type agent, $r = \theta_H/\theta_L$ and $\Delta R \geq 0$ to denote the difference of reservation utilities between the two agent types, $\Delta R = R_H - R_L$. To facilitate the presentation of the optimal decisions, the following terms are defined.

$$\left(\begin{array}{c} \psi_1 = \dfrac{1-\rho}{1-\rho/r^2}, \ \psi_2 = \dfrac{\rho}{1-(1-\rho)r^2}, \ r_c = \sqrt{\dfrac{1}{1-\rho}\left(1-\dfrac{\rho\theta_H^2}{2b}\right)} \\ K_1 = \dfrac{1}{2}(1-r^{-2})\left(\dfrac{s_0\psi_1\theta_L}{2b-\psi_1\theta_L^2}\right)^2, \ K_2 = \dfrac{1}{2}(1-r^{-2})\left(\dfrac{s_0\theta_L}{2b-\theta_L^2}\right)^2 \\ K_3 = \dfrac{1}{2}(r^2-1)\left(\dfrac{s_0\theta_H}{2b-\theta_H^2}\right)^2, \ K_4 = \dfrac{1}{2}(r^2-1)\left(\dfrac{s_0\psi_2\theta_H}{2b-\psi_2\theta_H^2}\right)^2. \end{array}\right) \tag{7}$$

It is easy to show that $0 < \psi_1 < 1$ and $K_1 < K_2 < K_3$, and $\psi_2 > 1$ and $K_3 < K_4$ when $r < r_c$. In addition, these values of $K$ constitute four distinct thresholds for the reservation utility difference, and $r_c$ serves as a threshold for the ability ratio under centralized pricing. The following proposition summarizes the decisions under the optimal separating and pooling contracts.

Proposition 1. *Under centralized pricing: (A) the optimal separating contracts exist when (i) $\Delta R \leq K_1$, (ii) $K_2 \leq \Delta R \leq K_3$, (iii) $\Delta R \geq K_4$ and $r < r_c$; (B) the optimal pooling contract exists for any value of $\Delta R$, except when $K_2 < \Delta R < K_3$. The decisions with respect to the optimal separating and pooling contacts are presented in Tables A1 and A2 in the Appendix, respectively.*

Thresholds $K_1$ and $K_2$ represent the differences between the costs of meeting low quotas $q_{L1}^*$ and $q_{L2}^*$ by the low- and high-type agents, respectively. Likewise, $K_3$ and $K_4$ are the differences between the costs of meeting high quotas $q_{H1}^*$ and $q_{H2}^*$, respectively.

Proposition 1(A) shows that under the optimal separating contracts, the price and the quota for a high-type agent are higher than those for a low-type one, resulting in the greater effort of the former than the latter. However, the optimal separating contracts are sometimes impossible for the firm, depending on the trade-off between the reservation utility difference and cost difference. In contrast to the standard contract theory, in which different agent types have the same reservation utility to ensure that the optimal separating contracts always exist (Bolton and Dewatripont 2005), our study infers that no optimal separating contracts exist when the difference of reservation utilities is moderate (between $K_1$ and $K_2$ or between $K_3$ and $K_4$) or when both the difference and the ability ratio are large (i.e., greater than $K_4$ and no less than $r_c$, respectively). The reason is that we cannot find two different contracts, that can simultaneously satisfy all IR and IC constraints in problem $\mathbf{P_c}$. Therefore, these conflicts always arise within the IR and IC constraints for any two different contracts, which can be referred to as the *conflicted screening* effect.

Considering the conflicted screening effect, the firm should consider the centralized pooling contract $\{t, q, p\}$ for the two agent types. Proposition 1(B) shows that when the difference of reservation utilities is between $K_2$ and $K_3$, there is no optimal pooling contract for two agent types. Under the optimal pooling contract, if $\Delta R \leq K_2$, then the IR constraint for the low type is binding. This result indicates that the quota is essentially designed for the low type. The opposite is true when $\Delta R \geq K_3$. When $K_2 < \Delta R < K_3$, no optimal pooling contract can satisfy the two IR constraints simultaneously. This scenario results in what we refer to as the *conflicted pooling* effect.

According to Proposition 1, if the optimal separating contracts do not exist for a certain range of $\Delta R$, then the optimal pooling contract must exist. The conflicted screening and pooling effects do not simultaneously arise under centralized pricing so that an optimal contract can always be offered. Moreover, under centralized pricing, the optimal separating contracts perform better (for the firm) than the optimal pooling contract when both are possible (e.g., in regions $\Delta R \leq K_1$ and $\Delta R \geq K_4$ (if $r < r_c$)). Table 1 presents the optimal contracts under centralized pricing for the entire spectrum of reservation utility difference. A pooling contract can be adopted when separating ones are unavailable.

Table 1 also presents the premiums received by the two agent types, which are the differences between agents' profits and reservation utilities. Furthermore, Table 1 shows the comparison of the respective efforts exerted by the agents and the efforts exerted if the agents were part of a homogeneous sales force. Note

**Table 1 Optimal Contracts and Related Premiums under *Centralized* Pricing; Optimal Effort Comparisons Between Heterogeneous and Homogeneous Sales Forces**

| Region | | Optimal contract | Premium $P_H$ | Premium $P_L$ | Effort $e_H$ | Effort $e_L$ |
|---|---|---|---|---|---|---|
| $\Delta R \le K_1$ | | Separating | $K_1 - \Delta R$ | 0 | Same | Lower |
| $K_1 < \Delta R < K_2$ | | Pooling-L | $K_2 - \Delta R$ | 0 | Lower | Same |
| $K_2 \le \Delta R \le K_3$ | | Separating | 0 | 0 | Same | Same |
| $K_3 < \Delta R < K_4$ | | Pooling-H | 0 | $\Delta R - K_3$ | Same | Higher |
| $\Delta R \ge K_4$ | $r < r_c$ | Separating | 0 | $\Delta R - K_4$ | Higher | Same |
| | $r \ge r_c$ | Pooling-H | 0 | $\Delta R - K_3$ | Same | Higher |

that in the optimal contract for homogeneous agents (with ability $\theta_i$), agents' optimal sales effort is calculated as $s_0\theta_i/(2b - \theta_i^2)$.

When $\Delta R \le K_1$, the optimal contracts are separating ones, and the high-type agent receives a positive premium, whereas no premium is offered to the low-type agent. The premium $K_1 - \Delta R$ increases with the low-type agent's quota. Compared with that in the homogeneous case, the quota for the low-type agent under this scenario (low quota $q^*_{L1}$) is distorted downward to reduce the premium; such distortion also reduces the low-type agent's effort. When $K_1 < \Delta R < K_2$, the optimal contract is a pooling one for the low-type agent, and the high type receives a premium (because he needs less effort to reach the quota). When $K_2 \le \Delta R \le K_3$, no premium is necessary under the optimal contracts (separating), and both agent types exert the same effort as if they were homogeneous. When $K_3 < \Delta R < K_4$ or when $\Delta R \ge K_4$ and $r \ge r_c$, the optimal contract is a pooling one for the high type. In this case, the low-type agent receives a positive premium and exerts greater effort than in the absence of a premium. When $\Delta R \ge K_4$ and $r < r_c$, the optimal contracts become separating ones, and the low-type agent receives a positive premium that decreases with the high-type agent's quota. Therefore, compared with the homogeneous case, the firm sets a higher quota (high quota $q^*_{H2}$) for the high-type agent to reduce the low-type agent's premium and thus encourages the former to increase his effort.

For a heterogeneous sales force with a common reservation utility, Rao (1990) found that all, except the agent with the lowest ability receive a premium, and all, except the agent with the highest ability expend less effort than the agents who were members of a homogeneous sales force. However, this conclusion is not applicable for our setup with type-dependent reservation utility. Under centralized pricing, when $K_2 \le \Delta R \le K_3$, both agent types receive no premium and work as hard as they would if the sales forces were homogeneous. When $\Delta R > K_3$, the low-type agent receives a positive premium, whereas the high-type one receives none; two agent types can work as hard as or even harder than they would if the sales forces were homogeneous.

For a general principal-agent problem with a continuous type of reservation utility relation, Lewis and Sappington (1989) found that the optimal contract involves pooling, and Maggi and Rodriguez-Clare (1995) showed that the condition when the pooling can occur depends on the relationship between reservation utility and type. Our result reveals explicitly how the optimal contracts (separating or pooling) rely on the difference of reservation utilities, and we only require a high reservation utility for a high-type agent.

### 4.2. Contracts under Delegated Pricing

In this subsection, we consider problem $\mathbf{P_d}$. Examining the optimal separating contracts for $\mathbf{P_c}$, we can propose the following possible solution for $\mathbf{P_d}$ ($i = H$ or $L$):

$$t_i(s,p) = \begin{cases} t_i^* & \text{if } p = p_i^* \text{ and } s = q_i^* \\ t_0 & \text{otherwise,} \end{cases}$$

where $\{t_i^*, q_i^*, p_i^*\}$ are from the optimal separating contracts for $\mathbf{P_c}$ (Table A1), and $t_0$ is sufficiently small and cannot satisfy agents' reservation utilities. Clearly, when $\{t_H(s,p), t_L(s,p)\}$ is offered, a high-type agent will choose $t_H(s,p)$ with pricing at $p_H^*$ and realizing sales $q_H^*$, whereas a low-type agent will choose $t_L(s,p)$ with pricing at $p_L^*$ and realizing sales $q_L^*$.

In other words, when pricing is delegated to the agent, the firm can set the contract such that if the price desired by the firm (under centralization) is not selected by the agent, the compensation to the agent is less than his reservation utility. Since the same price and realized sales can be anticipated under price delegation, the firm will achieve the same profit under either price delegation or price centralization. Similar arguments are used by Lal (1986) and Mishra and Prasad (2004). In summary, on the basis of the deterministic demand function, when the optimal separating contracts exist under centralized pricing (delegated pricing), the firm can design the optimal separating contracts under delegation (centralization) to realize the same profit.

However, under centralized pricing for some reservation utility difference $\Delta R$, the optimal separating contracts do not exist due to the conflicted screening effect (Table 1). When the optimal contract under centralization is the pooling contract, the performance of price centralization relative to price delegation remains unclear. Similar to the method of Lal (1986), we will not solve for the optimal solution under delegated pricing, but instead develop a feasible solution for the firm to provide reference for selecting centralized or delegated pricing.

We propose the following contract form, $t(s, p) = \alpha + (p - y) \times s$, where $\alpha$ is the fixed compensation awarded to the agent, and $y$ is the share received by the firm from the agent for each unit of sales. This form is commonly adopted under price delegation (e.g., Bhardwaj 2001), and we refer to it as margin-based commission (MBC) contract since $p - y$ denotes the commission that the agent obtains for each sale. Under this form, the pair of contracts offered by the firm becomes $\{(\alpha_H, y_H),(\alpha_L, y_L)\}$, and substituting them into the firm's problem $\mathbf{P_d}$ yields the following $\mathbf{P'_d}$.

$$\mathbf{P'_d}: \max \Pi_d(\alpha_H, y_H, \alpha_L, y_L) = \rho(y_H \times s_{HH} - \alpha_H) + (1-\rho)(y_L \times s_{LL} - \alpha_L).$$

$$s.t. \begin{array}{ll} (I) & \alpha_H + (p_{HH} - y_H)s_{HH} - c(e_{HH}) \geq R_H \\ (II) & \alpha_L + (p_{LL} - y_L)s_{LL} - c(e_{LL}) \geq R_L \\ (III) & \alpha_H + (p_{HH} - y_H)s_{HH} - c(e_{HH}) \geq \alpha_L + (p_{HL} - y_L)s_{HL} - c(e_{HL}) \\ (IV) & \alpha_L + (p_{LL} - y_L)s_{LL} - c(e_{LL}) \geq \alpha_H + (p_{LH} - y_H)s_{LH} - c(e_{LH}) \\ (V) & (p_{ix}, e_{ix}) = \arg\max \alpha_x + (p_{ix} - y_x)s_{ix} - c(e_{ix}), \quad i,x = H \text{ or } L \end{array} \quad (8)$$

Before presenting the results, the following terms are defined.

$$\begin{cases} V_1^s = \dfrac{s_0^2(\theta_H^2 - \theta_L^2)(2b - \theta_H^2)}{2(2b-\theta_L^2)[2b - \theta_H^2 + \rho(\theta_H^2 - \theta_L^2)/(1-\rho)]^2}, \\ V_2^s = \dfrac{s_0^2(\theta_H^2 - \theta_L^2)(2b - \theta_L^2)}{2(2b-\theta_H^2)[2b - \theta_L^2 - (1-\rho)(\theta_H^2 - \theta_L^2)/\rho]^2}, \\ V_1^p = \dfrac{s_0^2(\theta_H^2 - \theta_L^2)[2b - (1-\rho)\theta_H^2 - \rho\theta_L^2]^2}{2(2b-\theta_H^2)(2b-\theta_L^2)[2b - (1-2\rho)\theta_H^2 - 2\rho\theta_L^2]^2}, \\ V_2^p = \dfrac{s_0^2(\theta_H^2 - \theta_L^2)[2b - (1-\rho)\theta_H^2 - \rho\theta_L^2]^2}{2(2b-\theta_H^2)(2b-\theta_L^2)[2b - 2(1-\rho)\theta_H^2 + (1-2\rho)\theta_L^2]^2}, \\ r_d = \sqrt{1 + \rho(2b - \theta_L^2)/[(1-\rho)\theta_L^2]}. \end{cases} \quad (9)$$

We can verify that $V_1^s < V_1^p < V_2^p$. In addition, $V_2^p < V_2^s$ if $r < r_d$.

PROPOSITION 2. *For MBC contract $t(s, p) = \alpha + (p - y) \times s$ under price delegation: (A) a unique pair of optimal separating plans exists provided that (i) $\Delta R \leq V_1^s$ or (ii) $\Delta R \geq V_2^s$ and $r < r_d$; otherwise, no optimal separating plans exist; and (B) a unique optimal pooling plan exists except for $< \Delta R < K_2^s$. The optimal decisions in the separating and pooling plans are presented in Tables A3 and A4, respectively.*

For MBC contract $t(s,p) = \alpha + (p - y)\times s$, the optimal separating plans (i.e., $\{\alpha_H, y_H\}$ and $\{\alpha_L, y_L\}$ in Table A3) show that $y_H^* = 0$ and $\alpha_H^* < 0$ when $\Delta R \leq V_1^s$, that is, the firm does not collect revenue from each unit of sales, instead the agent should pay a lump sum to the firm for the total quantity he intends to sell (i.e., buy out from the firm and then sell to customers). The implication of this scenario is that if the reservation utility difference is small, then the firm should offer the high-type agent a buyout contract, and the low-type agent a regular contract (i.e., $y_L^* > 0$). However, if the reservation utility difference is large and the ability ratio is small, the low-type agent is offered a buyout contract. In this case, the high-type agent is offered an "enhanced" buyout contract, where he receives a bonus from the firm for each unit of sales ($y_H^* < 0$). It is interesting that the firm can separate different agent types only by granting one or both agent types total sales control (i.e., offering a buyout contract when the pricing has already been delegated). The expression $V_1^s$ ($V_2^s$) is the difference between the reward of the high-type agent and the reward of the low-type agent when the selected contract is intended for the low (high) type. Similar to the case of centralized pricing, $V_1^s$ and $V_2^s$ serve as the thresholds of the reservation utility difference that determine if separating plans are possible. The conflicted screening effect appears when (i) $V_1^s < \Delta R < V_2^s$ and (ii) $\Delta R \geq V_2^s$ and $r \geq r_d$.

When the conflicted screening effect arises, the firm should consider the delegated pooling MBC contract $\{\alpha, y\}$. Note that for $\Delta R \leq V_1^p$ ($\Delta R \geq V_2^p$), the IR constraint for the low- (high-) type agent is binding (from the proof of Proposition 2 in the Appendix). This result implies that under the respective conditions, the optimal pooling MBC contract is essentially designed for either agent type (i.e., the pooling of the low/high-type agent).

Similarly, $V_1^p$ ($V_2^p$) is the difference between the rewards of the high- and low-type agents when the optimal pooling MBC contract is of the low (high) type. For convenience, we refer to the $V$ function as the reward difference under delegated pricing. When $V_1^p < \Delta R < V_2^p$, no pooling MBC contract can simultaneously satisfy the two IR constraints due to the conflicted pooling effect. Therefore, under delegated pricing, neither optimal separating nor pooling MBC contracts exist when $V_1^p < \Delta R < V_2^p$ because the conflicted screening and conflicted pooling effects are both operative. When $\Delta R \le V_1^s$ or when $\Delta R \ge V_2^s$ and $r < r_d$, the optimal separating and pooling MBC contracts can exist. Under these circumstances, the firm performs better with the former than with the latter. Table 2 summarizes the optimal MBC contracts under delegated pricing for the entire spectrum of the reservation utility difference. Similar to centralization, the pooling MBC contract can be adopted under delegation only when separating ones are not available.

Table 2 also presents the premiums received by the two agent types with the optimal MBC contracts and compares the respective efforts the agents exert with the efforts if the agents were part of a homogeneous sales force. From Proposition 2, the optimal effort of type-$i$ agent weakly decreases in $y_i$ because $y_i$ is the per unit profit that the firm receives from the agent. When $\Delta R \le V_1^s$, separating MBC contracts are offered, and the firm sets a positive $y_L$ to reduce the premium received by the high-type agent, although at the cost of the lower effort from the low-type one. When $V_1^s < \Delta R \le V_1^p$, however, the firm offers a pooling MBC contract designed for the low-type agent and sets a positive $y$ to reduce the premium given to the high-type agent, consequently garnering a reduced effort from two types. When $V_2^p \le \Delta R < V_2^s$, a pooling MBC contract for the high-type agent is offered, and the low-type agent receives a positive premium. In this case, the firm sets $y < 0$ for the optimal plan (i.e., a buyout contract) to minimize the premium, and both agent types exert higher efforts than if they were part of a homogeneous sales force. When $\Delta R \ge V_2^s$ and $r < r_d$, separating MBC contracts are offered, and the low-type agent receives a positive premium. To reduce this premium, the firm (i) sets $y_H < 0$, which motivates the high type to exert more effort than in the homogeneous agents scenario, and (ii) sets $y_L = 0$, which motivates the low type to exert the same effort as in that scenario. If $r \ge r_d$, then a pooling MBC contract is optimal for $\Delta R \ge V_2^s$, which is the same as that for $V_2^p \le \Delta R < V_2^s$.

In conclusion, under delegated pricing with MBC contract, if $\Delta R \ge V_2^p$: (a) a low-type agent always receives a positive premium, whereas a high-type agent receives none and (b) the high- and low-type agents always work harder or equally hard, as they would if the sales forces were homogeneous. Thus, irrespective of whether the firm's pricing scheme is delegated or centralized, either agent type (high or low) with type-dependent reservation utility may receive zero premium and exert the same or greater effort than if he were a part of a homogeneous sales force.

### 4.3. Delegated or Centralized

To determine the right pricing scheme, we compare the performances of the contracts under centralized and delegated pricing. It is easy to verify for the $K$ and $V$ thresholds (i.e., effort cost and reward differences), that $K_2 < V_2^p$. For the ability ratio thresholds, $r_c < r_d$. The firm's pricing strategy and contract choice can now be identified from the findings in sections 4.1 and 4.2.

Proposition 3. *(A) When the centralized optimal contracts are separating contracts for (i) $\Delta R \le K_1$, (ii) $K_2 \le \Delta R \le K_3$, or (iii) $\Delta R \ge K_4$ and $r < r_c$, centralization and delegation can perform the same for the firm. (B) When the centralized optimal contract is pooling contract, delegation with the optimal MBC contract $t(s,p) = \alpha + (p - y)\times s$ performs better than centralization.*

With the optimal separating contracts under centralization, the firm has the flexibility to set different prices for different agent types. This allows the firm to anticipate the agent's pricing under delegation and set the anticipated price of different agent types in the centralized contract. Therefore, the optimal centralized and delegated separating contracts perform the same for the firm.

Note that the conflicted screening effect arises in certain ranges of the reservation utility difference and ability ratio, which excludes the existence of the optimal separating contracts under centralized pricing. In such a case, the optimal contract under centralization is the pooling one. However, under delegated pricing, for the MBC contract, the conflicted screening effect does not arise under certain conditions within the same ranges. Note that the optimal separating MBC contracts can always generate higher profit for the

**Table 2 Optimal Margin-Based Commission (MBC) Contracts and Related Premiums (Information Rents) under *Delegated* Pricing; Optimal Effort of MBC Contracts Comparisons Between Heterogeneous and Homogeneous Sales Forces (N/A = not applicable)**

| Region | | Optimal plan | Premium $P_H$ | Premium $P_L$ | Effort $e_H$ | Effort $e_L$ |
|---|---|---|---|---|---|---|
| $\Delta R \le V_1^s$ | | Separating | $V_1^s - \Delta R$ | 0 | Same | Lower |
| $V_1^s < \Delta R \le V_1^p$ | | Pooling-L | $V_1^p - \Delta R$ | 0 | Lower | Lower |
| $V_1^p < \Delta R < V_2^p$ | | **No equilibrium** | N/A | N/A | N/A | N/A |
| $V_2^p \le \Delta R < V_2^s$ | | Pooling-H | 0 | $\Delta R - V_2^p$ | Higher | Higher |
| $\Delta R \ge V_2^s$ | $r < r_d$ | Separating | 0 | $\Delta R - V_2^s$ | Higher | Same |
| | $r \ge r_d$ | Pooling-H | 0 | $\Delta R - V_2^p$ | Higher | Higher |

firm than the optimal pooling one (Table 2). Therefore, to determine centralization or delegation when the optimal contract under centralization is pooling, we should first compare between centralized pooling and delegated pooling (of MBC contract).

With delegated pooling, different agent types can set different prices despite having a single contract. By contrast, there is only a single price with centralized pooling. Thus, delegated pooling allows for greater pricing flexibility than centralized pooling. While, the comparison of Propositions 1 and 2 shows that the low-type agent always exerts less effort under delegated optimal pooling MBC contract than under centralized optimal pooling contract. Therefore, choosing between delegated and centralized pooling requires an evaluation of the trade-off between the benefit of pricing flexibility and the cost of reducing the incentive for sales effort.

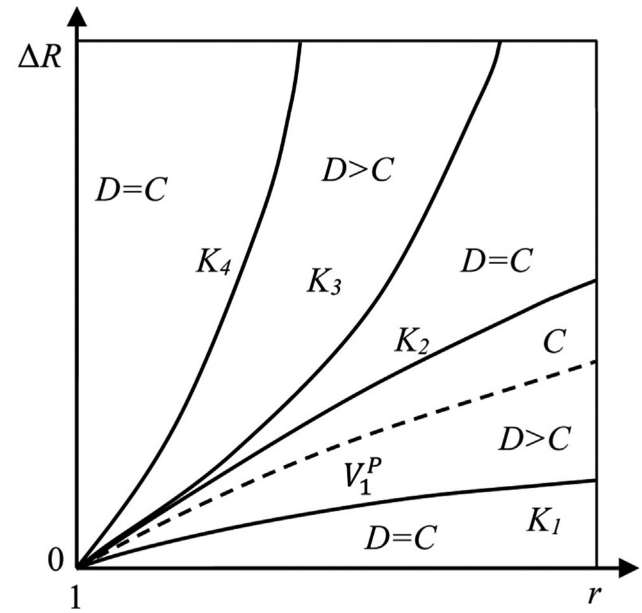
PROPOSITION 4. *When the pooling contract is offered under both pricing schemes, the firm can benefit from selecting delegated pricing (with the optimal MBC contract $t(s,p) = \alpha + (p - y) \times s$) over centralized pricing (with the optimal pooling contract).*

Based on the fact that the optimal separating MBC contracts (if available) work better than the pooling one, and together with Proposition 4, we have a full explanation of Proposition 3(B). Figure 1 illustrates the results of Proposition 3 when the ability ratio is small (i.e., $r < r_c$), where $C$ and $D$ represent centralization and delegation, respectively. When $r \geq r_c$, in the region $\Delta R \geq K_4$, delegation with the optimal MBC contracts always works better than centralization with the optimal pooling contract. In the region $V_1^p < \Delta R < K_2$, the firm selects centralization because there is no equilibrium MBC contract under delegation.

Lal (1986) showed that delegation and centralization are identical to the firm when there is no information asymmetry between the firm and the agent; while when the agent has more precise information about demand, delegation is preferred by the firm. The private information in Lal (1986) is acquired after the agent signs the contract and exerts effort. Different from Lal (1986), in our model, the agent possesses private information on ability and reservation utility (type-dependent) before signing the contract. Our results show that when there is asymmetric information between the firm and the agent, delegation and centralization can also work identically for the firm under certain conditions.

Mishra and Prasad (2004) considered the same sequence of events as in our model, but the agents in their model have the same reservation utility. They discovered that the performance of the centralized

**Figure 1 Pricing Scheme with $r < r_c$**




separating contracts for the firm is at least as good as that of the delegated separating contracts. Our result of Proposition 3(A) extends their findings in the scenario of type-dependent reservation utility when the difference of reservation utilities is small or when the difference is large but the ability gap is small, that is the conflicted screening effect does not appear under centralization. While when a conflicted screening effect is present under centralized pricing, the optimal contract becomes the pooling one. In this scenario, delegated pricing with the optimal separating MBC contracts can eliminate this effect when the difference of reservation utilities is moderate (i.e., $K_1 < \Delta R \leq V_1^s$) or large with moderate ability ratio (i.e., $\Delta R \geq V_2^s$ and $r_c \leq r < r_d$); delegation with the optimal pooling MBC contract performs better than centralization when $V_1^s < \Delta R < \min\{V_1^p, K_2\}$ or $\Delta R \geq V_2^p$ and $r \geq r_d$.

Lo et al. (2016) mentioned that agents who sell similar industrial equipment products are typically paid in accordance with the same compensation plan, which is not tailored to individual agents' characteristics. They also highlight that under the same contract, the more capable sales agents are granted higher pricing authority. The findings of Mishra and Prasad (2004) regarding the choice of centralization is based on the assumption that the firm designs different contracts for different types of sales agents. Hence, their analysis cannot explain the observation of Lo et al. (2016) regarding a unique contract with delegation. Our results, which are derived from the perspective of type-dependent reservation utility, can provide an explanation for the phenomenon where the firm offers a unique contract to agents with different abilities while delegating the pricing decision.

# 5. Extensions

### 5.1. Pricing Scheme and Compensation under Sales Uncertainty

The deterministic demand of the base model leads to the problem of false moral hazard, since the firm can infer the agent's effort from the realized sales and the prices charged.[5] In this subsection, by relaxing this assumption, we examine how sales uncertainty affects the firm's decisions and our main findings in section 4.

Now consider the uncertain realized sales $\tilde{s}$:

$$\tilde{s} = s + \varepsilon = s_0 + \theta e - bp + \varepsilon, \tag{10}$$

where $\varepsilon$ represents the random noise with $E(\varepsilon) = 0$. The additive form of the uncertainty is commonly used in literature (Holmstrom and Milgrom 1991). Moreover, $\varepsilon$ is independent of agents. Considering the presence of uncertainty, $\tilde{s}$ is observed (not $s$ of Equation (1)), which is an unbiased estimate of $s$ as $E(\varepsilon) = 0$.

Before deriving the centralized optimal contracts with uncertain demand, we first rewrite the contracts under deterministic demand in Proposition 1. According to Rao (1990),[6] the optimal centralized contracts in Tables A1 and A2 can be replaced by a menu of linear plans on realized sales. Considering the optimal contracts $\{t_x(q_x),p_x\}$ for a certain reservation utility difference $\Delta R$, the contracts can be represented by $\{t_x(s),p_x\}$ because the realized sales $s$ is the same as the quota $q_x$ without uncertainty. The linear plan is thus given by $C_x(s;q_x) = t_{0x}(q_x) + \beta_x(q_x)(s - q_x)$, where $t_{0x}(q_x) = t_x(q_x)$ and $\beta_x(q_x) = \frac{dt_x(s)}{ds|_{s=q_x}}$. When the firm offers linear contracts to agents, quota $q_x$ and the related payment are included, where $t_{0x}(q_x)$ denotes the fixed compensation to the agent if quota $q_x$ is realized, and $\beta_x(q_x)$ denotes the bonus/penalty for each unit of sales above/below the quota. The optimal contracts of the linear forms on sales and related price under centralized pricing are summarized in Table A5 in the Appendix. In the absence of uncertainty in the demand, the agent exerts the effort that realizes the quota that he selects (i.e., $s = q_x$). Separating or pooling contracts are provided when the conflicted screening effect does not appear or appears, respectively.

It can be predicted that the centralized optimal contracts under deterministic demand (Table A5) is also optimal under uncertain demand, with $s$ being replaced by $\tilde{s}$. This observation is based on the fact that type-$i$ agent decides his effort $e_{ix}$ to maximize his expected reward $E[V_i(e,x)]$ after choosing contract $C_x(\tilde{s};q_x)$ with price $p_x$ $(i,x = H,L)$, where

$$\begin{aligned} E[V_i(e,x)] &= E[C_x(\tilde{s};q_x)] - c(e_{ix}) \\ &= C_x(s;q_x) - c(e_{ix}) = C_x(q_x;q_x) - c(e_{ix}). \end{aligned} \tag{11}$$

Equation (11) shows that the agent makes the same effort under contract $C_x(\tilde{s};q_x)$ as in the deterministic scenario with contract $C_x(s;q_x)$, because his expected profit is independent of uncertainty $\varepsilon$. Therefore, similar to the deterministic demand scenario of centralized pricing, under uncertain demand, when the conflicted screening effect arises, no optimal separating contracts are available; optimal pooling contract, however, can be offered. For these cases, we consider the option of delegation with MBC contract $t(\tilde{s},p) = \alpha + (p - y)\tilde{s}$. The expected profit for type-$i$ agent after selecting contract $\{\alpha_x, y_x\}$ is expressed as

$$\begin{aligned} E[V_i(p,e,x)] &= E[\alpha_x + (p_{ix} - y_x) \times \tilde{s}] - c(e_{ix}) \\ &= \alpha_x + (p_{ix} - y_x) \times s_{ix} - c(e_{ix}). \end{aligned} \tag{12}$$

Anticipating that the agent's behavior under uncertain demand is the same with that under deterministic demand, the optimal decisions of $\alpha$ and $y$ for different $\Delta R$ are summarized in Tables A3 and A4 in the Appendix.

Proposition 5. *The results from our base model hold when uncertainty is present in the demand.*

On the basis of the optimal separating contracts under centralized pricing, when delegating the price decision to the agent, the firm can always realize the same performance through a proper contract design to induce the agents to set the same price and make the same effort as that under centralization. Moreover, when the conflicted screening effect exists, the firm prefers delegation over centralization for the pricing flexibility. Thus, the results of Proposition 3 are applicable in this context.

### 5.2. Effect of Correlation across Sales Territories

In our base model, we assume that agents have mutually exclusive sales territories. In practice, the sales of each territory can be correlated. Therefore, the effect of the correlation across territories on the firm's pricing schemes should be investigated. We consider the case with two territories A (existing/old territory) and B (new territory). The firm knows the ability of the sales agent in territory A and thus offers the contract with zero premium to the agent. For territory B, the firm may face two agent types (with high or low abilities). As previously mentioned, type is the agent's private information. Given that the firm provides the same product in the two territories, the prices are the same across territories. For simplicity, we assume a unidirectional and exogenous cross-territory effect (e.g., Abhishek et al. 2016), which can be modeled through the realized sales for territories A and B:

$$s_A = s_{0A} + \theta_A e_A - bp + \tau s_B \quad \text{and} \quad s_B = s_{0B} + \theta_B e_B - bp,$$

where subscripts $A$ and $B$ represent territory A and B, respectively, and $\tau$, $\tau \in [-1, 1]$ denotes the correlation across the territories and represents the change in the sales in territory A imposed by the unit sales in territory B. Provided that the ability and reservation utility of the agent in territory A are common knowledge, we concentrate on the centralization or delegation decision of the firm in territory B. Under centralized pricing, the firm decides the price(s) and compensation contracts to maximize the total expected profit from the two territories. Under delegated pricing, given that the agent sets the price in territory B, the contract for territory A also depends on the price in B due to the same price strategy. By solving the firm's problems under centralization and delegation, we obtain Proposition 6.

Proposition 6. *The results from our base model remain qualitative when a correlation is present among the sales territories. The regions (of reservation utility difference) where the conflicted screening effect exists shrink when the positive correlation increases or when the negative correlation decreases.*

When $\tau > 0$, the correlation across sales territories is positive, which means that each unit of sales in the new territory B generates $\tau$ units of additional sales in territory A. This phenomenon occurs due to the "network effect" (Abhishek et al. 2016). Otherwise, the sales in territory B negatively affects territory A (i.e., $\tau < 0$). Proposition 6 first asserts that the results from the base model hold qualitatively. The optimal separating contracts perform equally under centralized and delegated pricing. Delegation with the optimal MBC contracts can perform better than centralization with the optimal pooling contract if the conflicted screening effect exists under centralized pricing. Note that the increase in the correlation signifies a strong positive correlation or a large absolute value of the negative correlation ($|\tau|$). This proposition also shows that the regions, where delegated pricing with the optimal MBC contracts works better than the centralized optimal pooling contract, shrink if the positive correlation increases (i.e., $\tau > 0$ and $\tau$ increases) or the negative correlation decreases (i.e., $\tau < 0$ and $|\tau|$ decreases). That is, when the sales in territory B lead to more increase (for $\tau > 0$) or less decrease (for $\tau < 0$) in sales in territory A, in more regions of reservation utility difference $\Delta R$, the firm can avoid the discrimination between centralization and delegation because the two pricing schemes with optimal separating contracts can perform equally.

### 5.3. Continuous Type

In this subsection, we check how our main results may change when the type distribution is continuous. Our main findings with two discrete types show that the optimal contracts under centralized pricing can be separating contracts or pooling contract. When the optimal contracts under centralization are separating, centralization and delegation perform equally since the centralized pricing can be set according to the agent type. When the optimal contract under centralization is pooling, delegation performs better than centralization because of the flexibility of utilizing agent type information. Consider the problem with continuous type and type-dependent reservation utility. When centralized optimal contract are separating, we can show, following Mishra and Prasad (2004), that centralization works at least as well as delegation because the centralized pricing can be made for each type individually. As such, we remain to see if a continuous region (of type) exists within which the centralized optimal contract is pooling, and how centralized and delegated pooling contracts perform.

Consider a general type distribution $F(\theta)$ with density $f(\theta) > 0$ over $[\underline{\theta}, \bar{\theta}]$ $(0 < \underline{\theta} < \bar{\theta})$, and $\frac{F(\theta)}{f(\theta)}$ increasing in $\theta$ whereas $\frac{1-F(\theta)}{f(\theta)}$ decreasing in $\theta$. The reservation utility $R(\theta)$ is an increasing function of type $\theta$. Let $t(\theta)$ be the compensation and $e = g(q(\theta), p(\theta); \theta)$ be the effort for reaching quota $q(\theta)$ under centralized price $p(\theta)$. The principal-agent problem for the firm under centralization can be formulated as follows, where the superscript $L$ represents continuous type.

$$\mathbf{P_c^L}: \max \Pi_c(p(\theta), q(\theta), t(\theta)) = \int_{\underline{\theta}}^{\bar{\theta}} (p(\theta) \times q(\theta) - t(\theta)) f(\theta) d\theta$$

$$(IR) \quad t(\theta) - c(g(q(\theta), p(\theta); \theta)) \geq R(\theta) \text{ for all } \theta \in [\underline{\theta}, \bar{\theta}]$$

$$(IC) \quad t(\theta) - c(g(q(\theta), p(\theta); \theta)) \geq t(\hat{\theta}) - c(g(q(\hat{\theta}), p(\hat{\theta}); \theta))$$

$$\text{for all } \theta, \hat{\theta} \in [\underline{\theta}, \bar{\theta}].$$

The second constraint in $P_c^L$ can be restated as the decision problem of a type-$\theta$ agent $i$ who announces type $\hat{\theta}$ to maximize his profit:

$$\max_{\hat{\theta}} \quad V_i(\hat{\theta}; \theta) = t(\hat{\theta}) - c(g(q(\hat{\theta}), p(\hat{\theta}); \theta))$$

$$(IR) \quad V_i(\hat{\theta}; \theta) \geq R(\theta).$$

Assuming $R''(\theta) < 0$, a pooling region $\theta \in [\theta_1, \theta_2]$ $(\theta_1 \leq \theta_2)$ exists with the optimal contract under centralization for the above principal-agent problem

(Lemma 5 in Lewis and Sappington 1989 and Proposition 3 in Maggi and Rodriguez-Clare 1995). With the existence of a pooling region, we now compare delegated pooling with centralized pooling. The firm's problem with delegated pooling contract $t(s,p(\theta))$ can be formulated as follows.

$$\mathbf{P_d^L}: \max \quad \Pi_d(t(s,p(\theta))) = \int_{\underline{\theta}}^{\bar{\theta}} (p(\theta) \times s - t(s,p(\theta)))f(\theta)d\theta$$

$$(IR) \quad t(s,p(\theta)) - c(e) \geq R(\theta)$$
$$(IC) \quad (p(\theta),e) = \mathrm{argmax}\, t(s,p(\theta)) - c(e).$$

Although the sequences of events are different, our principal-agent model here with pooling contract is equivalent to that of Lal (1986)'s because neither model can screen the agent type. Thus, following the proof of Lal (1986), we can show that the firm is never worse off with delegated pooling contract and could be strictly better off in some situations compared with centralized pooling contract. Based on the above analysis, the firm can benefit from delegated pooling compared with centralized pooling when the agent type is continuous and reservation utility is type-dependent as in our base model. The advantage of delegation here is the same: under centralized pooling, the firm charges a single price with a single quota for all agent types; whereas under delegated pooling, the firm compensates the agent for the realized sales and the agent charges an appropriate price according to his private type information.

## 6. Conclusion

We find from our analysis that agent heterogeneity in both ability and reservation utility (type-dependent) has two effects on contract design: conflicted screening effect and conflicted pooling effect. Regardless of the pricing scheme, separating equilibrium contracts are not available in the presence of the conflicted screening effect whereas a pooling equilibrium contract is not available in the presence of the conflicted pooling effect. The firm, however, can always offer the optimal contract (separating or pooling) under centralized pricing because the conflicted screening effect and conflicted pooling effect never coexist under this pricing scheme; but the same cannot be said for delegated pricing with the MBC contract. The optimal (separating or pooling) contracts under centralization or delegation (with MBC contract) depend on the trade-offs between the differences in agents' reservation utilities and in their effort costs or rewards resulting from concealing their true types.

Regarding the important price delegation decision, we show that the optimal separating contracts generate the same profit under centralized and delegated pricing because under centralization the firm retains the same pricing flexibility as that of the agent under delegation. However, the optimal pooling MBC contract under delegation can perform better than the optimal pooling contract under centralization because the upside/benefit from the pricing flexibility of delegation exceeds the downside/cost caused by the reduced effort incentive. Therefore, under optimal contracts, centralized pricing and delegated pricing are indifferent to the firm when the reservation utility difference is small or when the difference is large and the ability gap is small because the firm can offer separating contracts; the firm prefers delegated pricing when the reservation utility difference is moderate or when both the difference and the ability gap are large because only a pooling contract can be offered under centralization. Our findings reveal that the agents' private information on ability and type-dependent reservation utility is related to the optimal decision of the pricing scheme, and this helps to explain the varied use, in practice, of price delegation combined with a unique contract for heterogeneous agents. We therefore recommend that before choosing between delegated and centralized pricing, the manager should assess her sales agents' abilities and reservation utilities. We further prove that the main results remain qualitative under the scenarios with uncertain demand, with correlation across sales territories and with continuous type.

We also draw insights on sales force compensation. By assuming type-dependent reservation utility, in contrast to the existing works on compensation, we find that at least one agent type (high or low) does not receive information rent and at least one agent type (high or low) exerts the first-best sales effort. In certain cases, the firm can design a compensation plan to learn agents' private information without paying any information rent; and, with the plan, all agents are motivated to work as hard as if they were homogeneous. The outcomes depend on how different the agents are in terms of ability and reservation utility, and on the interplay between agents' reservation utility differences and their effort costs or reward differences when they choose the contracts not intended for their types.

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## Notes

[1]This assumption is relaxed in an extension in which a correlation exists across the sales territories (section 5.2).

[2]The deterministic market potential assumption is relaxed in the extension (section 5.1), where we analyze the influence of the demand uncertainty. The main results are shown to be qualitatively unchanged. We thank the Senior Editor and Reviewers for suggesting this direction of extension.

[3]The base model of two agent types is extended to the continuous type in section 5.3.

[4]In the case of a centralized system, the firm determines the price and the effort that type-$i$ agent should exert to maximize $p(s_0 + \theta_i e - bp) - e^2/2$. To ensure the interior solution, we need $2b > \theta_i^2$ to have the negative definite Hessian matrix of the objective function. Then, the optimal price and effort are expressed as $p = s_0/(2b - \theta_i^2)$ and $e = (s_0\theta_i)/(2b - \theta_i^2)$, respectively. With the optimal price and effort, the maximum total profit under the centralized system is $s_0^2/[2(2b - \theta_i^2)]$, and the firm's maximum net profit is $s_0^2/[2(2b - \theta_i^2)] - R_i$. Hence, a sufficiently large $s_0$ can guarantee that the firm's profit is nonnegative.

[5]Laffont and Martimort (2001) called this moral hazard "false moral hazard" in page 274 because the agent does not have the freedom to choose his effort.

[6]Proposition 5 in Rao (1990), indicates that a necessary and sufficient condition for the optimal contracts and a menu of linear plans to be equivalent is the convexity of the optimal contracts in sales.

## References

Abhishek, V., K. Jerath, Z. Zhang. 2016. Agency selling or reselling? Channel structures in electronic retailing. *Management Sci.* **62**(8): 2259–2280.

Armstrong, M., D. E. M. Sappington. 2004. Toward a synthesis of models of regulatory policy design with limited information. *J. Regul. Econ.* **26**(1): 5–21.

Basu, A., R. Lal, V. Srinivasan, R. Staelin. 1985. Salesforce-compensation plans: An agency theoretic perspective. *Market. Sci.* **4**(4): 267–291.

Bhardwaj, P. 2001. Delegating pricing decisions. *Market. Sci.* **20**(2): 143–169.

Bolton, P., M. Dewatripont. 2005. *Contract Theory*. The MIT Press, Cambridge, Massachusetts, London, England.

Cakanyildirim, M., Q. Feng, X. Gan, S. Sethi. 2012. Contracting and coordination under asymmetric production cost information. *Prod. Oper. Manag.* **21**(2): 345–360.

Caldieraro, F., A. T. Coughlan. 2009. Optimal sales force diversification and group incentive payments. *Market. Sci.* **28**(6): 1009–1026.

Chakravarty, A., J. Zhang. 2007. Collaboration in contingent capacities with information asymmetry. *Naval Res Logist* **54**: 421–432.

Chen, F. 2000. Salesforce incentives and inventory management. *Manuf. Serv. Oper. Manag.* **2**(2): 186–202.

Chen, F. 2005. Salesforce incentives, market information, and production/inventory planning. *Management Sci.* **51**(1): 60–75.

Chen, Y., W. Xiao. 2012. Impact of reseller's forecasting accuracy on channel member performance. *Prod. Oper. Manag.* **21**(6): 1075–1089.

Chen, F., G. Lai, W. Xiao. 2016. Provision of incentives for information acquisition: Forecast-based contracts vs. menus of linear contracts. *Management Sci.* **62**(7): 1899–1914.

Chu, L., G. Lai. 2013. Salesforce contracting under demand censorship. *Manuf. Serv. Oper. Manag.* **15**(2): 320–334.

Dai, T., K. Jerath. 2013. Salesforce compensation with inventory considerations. *Management Sci.* **59**(11): 2490–2501.

Frenzen, H., A. Hansen, M. Krafft, M. Mantrala, S. Schmidt. 2010. Delegation of pricing authority to the sales force: An agency theoretic perspective of its determinants and impact on performance. *Int. J. Res. Market.* **27**(1): 58–68.

Fudenberg, D., J. Tirole. 1991. *Game Theory*. MIT Press, Cambridge.

Gan, X., Q. Feng, S. Sethi. 2019. Sourcing contract under countervailing incentives. *Prod. Oper. Manag.* **28**(10): 2486–2499.

Hansen, A., K. Joseph, M. Krafft. 2008. Price delegation in sales organizations: An empirical investigation. *Bus. Res.* **1**(1): 94–104.

Harris, M., R. M. Townsend. 1981. Resource allocation under asymmetric information. *Econometrica* **49**(1): 33–64.

Holmstrom, B., P. Milgrom. 1991. Multitask principal-agent analyses: Incentive contracts, asset owership, and job design. *J. Law Econ. Org.* **7**: 24–52.

Joseph, K. 2001. On the optimality of delegating pricing authority to the sales force. *J. Market.* **65**: 62–70.

Joseph, K., A. Thevaranjan. 1998. Monitoring and incentives in sales organizations: An agency-theoretic perspective. *Market. Sci.* **7**(2): 107–123.

Jullien, B. 2000. Participation constraints in adverse selection models. *J. Econ. Theory* **93**: 1–47.

Kala, A., M. Shi. 2001. Designing optimal sales contests: A theoretic perspective. *Market. Sci.* **20**(2): 170–193.

Kerschbamer, R., N. Maderner. 1998. Are two a good representative for many? *J. Econ. Theory* **83**: 1–47.

Kim, S. 1997. Limited liability and bonus contracts. *J. Econ. Manag. Strat.* **6-4**: 899–913.

Laffont, J., D. Martimort. 2001. *The Theory of Incentives I: The Principal-agent Model*. Princeton University Press, Princeton.

Laffont, J., J. Tirole. 1988. The dynamics of incentive contracts. *Econometrica* **56**(5): 1153–1175.

Laffont, J., J. Tirole. 1990. Adverse selection and renegotiation in procurement. *Rev. Econ. Stud.* **57**(4): 597–625.

Lal, R. 1986. Delegating pricing responsibility to the salesforce. *Market. Sci.* **5**(2): 159–168.

Lal, R., V. Srinivasan. 1993. Compensation plans for single- and multi-product salesforces: An application of the Holmstrom-Milgrom model. *Management Sci.* **39**(7): 777–793.

Lal, R., R. Staelin. 1986. Salesforce compensation plans in environments with asymmetric information. *Market. Sci.* **5**(3): 179–198.

Lewis, T., D. Sappington. 1989. Countervailing incentives in agency problems. *J. Econ. Theory* **49**: 294–313.

Lim, N., H. Ham. 2014. Relationship organization and pricing delegation: An experimental study. *Management Sci.* **60**(3): 586–605.

Lo, D., W. Dessein, M. Ghosh, F. Lafontaine. 2016. Price delegation and performance pay: Evidence from industrial sales forces. *J. Law Econ. Org.* **32**(3): 508–544.

Maggi, G., A. Rodriguez-Clare. 1995. On countervailing incentives in agency problems. *J. Econ. Theory* **66**: 238–263.

Mantrala, M., P. Sinha, A. Zoltners. 1994. Structuring a multiproducts sales quota-bonus plan for a heterogeneous salesforce: A practical model-based approach. *Market. Sci.* **13**(2): 121–144.

Mishra, B., A. Prasad. 2004. Centralized pricing versus delegating pricing to the salesforce under information asymmetry. *Market. Sci.* **23**(1): 21–27.

Mishra, B., A. Prasad. 2005. Delegating pricing decisions in competitive markets with symmetric and asymmetric information. *Market. Sci.* **24**(3): 490–497.

Misra S., A. Coughlan, C. Narasimhan. 2005. Salesforce compensation: An analytical and empirical examination of the agency theoretic approach. *Q. Market. Econ.* **3**: 5–39.

Murthy, P., M. Mantrala. 2005. Allocating a promotion budget between advertising and sales contest prizes: An integrated marketing communication perspective. *Market. Lett.* **16**(1): 19–35.

Nagar, V. 2002. Delegation and incentive compensation. *Acc Rev.* **77**: 379–395.

Oyer, P. 2000. A theory of sales quotas with limited liability and rent sharing. *J. Lab. Econ.* **18**: 405–426.

Park, E. 1995. Incentive contracting under limited liability. *J. Econ. Manag. Strat.* **4**: 477–490.

Raju, J., Srinivasan. 1996. Quota-based compensation plans for multiterritory heterogeneous salesforces. *Management Sci.* **42**: 1454–1462.

Rao, R. 1990. Compensating heterogeneous salesforces: Some explicit solutions. *Market. Sci.* **10**: 319–341.

Rubel, O., A. Prasad. 2016. Dynamic incentives in sales force compensation. *Market. Sci.* **35**(4): 676–689.

Simester, D., J. Zhang. 2014. Why do salespeople spend so much time lobbying for low prices? *Market. Sci.* **33**(6): 796–808.

Stephenson, P. R., W. L. Cron, G. L. Frazier. 1979. Delegating pricing authority to the sales force: The effects on sales and profit performance. *J. Market.* **43**(2): 21–28.

Weinberg, C. B. 1975. An optimal commission plan for salesman's control over prices. *Management Sci.* **21**(April): 937–943.

Yang, Y., N. Syam, J. Hess. 2013. Thrill of victory and agony of defeat: Emotional rewards and sales force compensation. *Q. Market. Econ.* **11**: 379–402.

## Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Online Supplement for Price Delegation or Not? The Effect of Heterogeneous Sales Agents