# Impact of reseller's and sales agent's forecasting accuracy in a multi-layer supply chain

*Ling-Chieh Kung (lckung@ntu.edu.tw)*
*Department of Information Management, National Taiwan University, Taiwan*

*Ying-Ju Chen*
*Department of Industrial Engineering and Operations Research,*
*University of California, Berkeley*

## Abstract
We consider a three-layer supply chain with a manufacturer, a reseller, and a sales agent. The random demand is stochastically determined by the random market condition and the sales agent's private effort level. While the manufacturer is uninformed about the market condition, the reseller and the sales agent conduct demand forecasting and generate private demand signals. Under this framework with two levels of adverse selection intertwined with moral hazard, we study the impact of the reseller's and the sales agent's forecasting accuracy on the performance of the supply chain and the profitability of each member. We show that supply chain performance and the manufacturer's profitability are convex on the reseller's forecasting accuracy. From the perspective of the supply chain and the manufacturer, typically improving the reseller's accuracy is detrimental when the accuracy is low but is beneficial when it is high. The concrete interrelation among the system-optimal reseller's accuracy, the volatility of the market condition, and the sales agent's accuracy is also identified.

**Keywords:** multi-level information asymmetry, demand forecasting accuracy, salesforce compensation.

### Introduction
In this paper, we consider a three-layer supply chain with a manufacturer, a reseller, and a sales agent. Our main interest is on the reseller's and the sales agent's demand forecasting capabilities. Past literature has documented the benefits of enhancing an upstream player's demand forecasting (Cachon and Fisher, 2000; Gavirneni et al., 1999; Lee et al., 2000). It is shown

therein that improving the upstream player's forecasting accuracy is unambiguously beneficial. Nevertheless, the potential detriments of improving the forecasting ability of the downstream player(s) have been demonstrated in some recent works, including Miyaoka and Hausman (2008), Shin and Tunca (2010), Taylor and Xiao (2010), and Chen and Xiao (2012). In these studies, increased degree of information asymmetry is recognized as a major disadvantage of improving a downstream player's forecasting accuracy. The primary departure from the existing work is the co-existence of multiple demand forecasters who hold different positions in a supply chain. This allows us to study the interrelation amongst different layers of supply chains with arbitrary composition of forecasting accuracy.

In pursuit of this goal, we construct a stylized three-layer supply chain with a manufacturer, a reseller, and a sales agent. The manufacturer delegates the selling business of a single product to the reseller, who then relies on the sales agent to exert private sales effort to promote the product. The sales outcome is stochastically determined by the sales effort and a random market condition, whose realization is unobservable to all players. Prior to the selling season, the reseller applies her retailing experience and marketing knowledge to perform demand forecasting and estimate the market condition. This demand forecast provides useful information to the reseller and creates an adverse selection problem in the manufacturer-reseller relationship. Similarly, the sales agent can utilize his close contact to end consumers and obtain his own demand signal. Such a private signal brings another adverse selection issue into the reseller-agent relationship. With the unobservability of the two demand signals and the sales effort, our model thus exhibits *two levels* of adverse selection intertwined with a moral hazard problem regarding the sales effort.

To deal with the reseller's informational advantage, the manufacturer offers the reseller a menu of contracts, in which each menu item defines the payment as a function of the sales outcome. Similarly, the reseller offers a menu of sales-contingent contracts to the sales agent. We characterize the optimal contracts for the manufacturer and the reseller as well as the sales agent's optimal effort decision. We show that supply chain performance, with the expected sales being an appropriate index in our context, is a convex function of the reseller's accuracy. Moreover, when the accuracy is low, an improvement in the reseller's accuracy typically hurts supply chain performance and the manufacturer's profitability. On the contrary, such an improvement becomes beneficial when the accuracy is high. The manufacturer's expected profit is shown to be proportional to the expected sales revenue and thus also convex.

Given the convexity result, it is natural to ask whether the reseller should be uninformed (with the lowest accuracy) or precise (with the highest accuracy) to optimize supply chain performance and the manufacturer's profitability. We show that the system-optimal reseller's accuracy depends on the volatility of the market condition and the sales agent's accuracy. In particular, when demand volatility is moderate, the sales agent's accuracy determines which reseller dominates: Because the better-monitoring effect is marginal if the sales agent's accuracy is low, the uninformed reseller is preferred when the sales agent is inaccurate. As delegating to the uninformed reseller is equivalent to operating a direct supply chain with only the manufacturer and the sales agent, our result also provides an implication on the manufacturer's selection of supply chain structure.

**Model**

We consider a supply chain in which a manufacturer sells a product through a reseller, who then relies on her sales agent to sell to the end market at a fixed price in a single selling season. The market demand $x$ is random and may be either high or low. The high demand volume is normalized to 1 and the low demand volume is normalized to 0. The realization of $x$ depends on a random market condition $\theta$ and the sales effort $a \geq 0$ privately exerted by the sales agent. More precisely, we assume that $\Pr(x = 1|\theta, a) = \theta a = 1 - \Pr(x = 0|\theta, a)$. It costs the sales agent $V(a) = \frac{1}{2}a^2$ for exerting effort $a$.

We assume that $\theta \in \{\theta_L, \theta_H\}, 0 < \theta_L < \theta_H < 1$, and denote the probability for the market condition to be bad as $\gamma$, i.e., $\Pr(\theta = \theta_L) \equiv \gamma = 1 - \Pr(\theta = \theta_H)$. Though we assume $\gamma = \frac{1}{2}$ to simplify our analysis in this paper, most our results can be generalized to any value of $\gamma$ between 0 and 1. Let $\eta \equiv \theta_H/\theta_L$ denote the market condition ratio, which turns out to be an important factor in our analysis. Throughout this paper, we assume that the manufacturer can deliver the products to the reseller after demand is realized and thus the demand quantity $x$ is also the sales outcome. Without loss of generality, we normalize the production cost to 0 and the selling price to 1.

While the manufacturer knows nothing about the market condition $\theta$, the reseller and the sales agent can estimate $\theta$ through independent demand forecasting. Prior to the selling season, the reseller obtains a demand signal $s_R$, which is either good ($s_R = G$) or bad ($s_R = B$). Under this setting, we define $\lambda_R \equiv \Pr(s_R = B|\theta = \theta_L) = \Pr(s_R = G|\theta = \theta_H)$ as the reseller's forecasting accuracy. Similarly, the sales agent can collect a demand signal $s_A$, which may be favorable ( $s_A = F$ ) or unfavorable ( $s_A = U$ ), with the forecasting accuracy $\lambda_A \equiv \Pr(s_A = U|\theta = \theta_L) = \Pr(s_A = F|\theta = \theta_H)$. We assume that $s_R$ and $s_A$ are independent, the manufacturer sees none of the two signals, and $\lambda_R$ and $\lambda_A$ are publicly observed by all members.

We assume the sales agent can observe both $s_R$ and $s_A$ but the reseller can only observe $s_R$. Though this assumption simplifies our analysis, it can be shown that disallowing the sales agent to observe the reseller's signal does not change our results by following the arguments by Maskin and Tirole (1990, 1992). Without loss of generality, it is assumed that $\lambda_R$ and $\lambda_A$ are between $\frac{1}{2}$ and 1. To highlight the impact of the informational issues, we ignore the costs of forecasting and improving accuracy. These costs can be easily patched in our setting in a straightforward manner.

Because the effort level $a$ is unobservable, the reseller can only compensate the sales agent according to the observable sales outcome $x$. Therefore, the best she can do is to offer a sales-contingent compensation scheme $T_A(x) = \alpha + \beta x$, where $\beta$ is a sales bonus. Because the sales agent has superior information about the market condition, the reseller's best strategy is to offer the sales agent a menu of contracts $\{(\alpha_F, \beta_F), (\alpha_U, \beta_U)\}$, where $(\alpha_j, \beta_j)$ defines the compensation scheme intended for the sales agent observing $s_A = j$. Similarly, the manufacturer may compensate the reseller $T_R(x) = u + vx$, where $v$ is the sales bonus. Because the manufacturer does not observe $s_R$, the manufacturer should offer the reseller a menu $\{(u_G, v_G), (u_B, v_B)\}$ so that it is in the reseller's best interest to choose $(u_k, v_k)$ if she observes signal $s_R = k \in \{G, B\}$. We assume all the players are risk-neutral and act to maximize their expected profits. Without loss of generality, we normalize the reseller's and the sales agent's reservation net incomes to 0.

The sequence of events is as follows: 1) The reseller and the sales agent determine their accuracy $\lambda_R$ and $\lambda_A$, respectively. Once determined, $\lambda_R$ and $\lambda_A$ are publicly observed by everyone. 2) The market condition $\theta$ is realized but observed by no one. The reseller and the sales agent conduct forecasting and observe the demand signals $s_R$ and $s_A$, respectively. 3) The manufacturer offers a menu for the reseller to choose one contract from; 4) Based on the demand signal $s_R$ and the chosen contract, the reseller offers a menu for the sales agent to choose one contract from. In these two stages, if either the reseller or the sales agent rejects the offer, the game ends and every supply chain member receives a null payoff. 5) Based on the signals $s_R$ and $s_A$ and the chosen contract, the sales agent exerts sales effort $a\%$ ; 6) The demand quantity $x$ is realized, the sales revenue goes to the manufacturer, and the reseller and the sales agent receive their payments according to the chosen contracts and the realization of $x$.

**Analysis**

In this section, we characterize the optimal menus of contracts offered by the manufacturer and the reseller. The impact of the reseller's and sales agent's forecasting accuracy on supply chain performance and the profitability of supply chain members is then discussed. For ease of exposition, let the type-$(j,k)$ sales agent be the sales agent observing signals $s_A = j$ and $s_R = k$ and the type-$k$ reseller be the reseller observing signal $s_R = k$, where $j \in \{F, U\}$ and $k \in \{G, B\}$. Due to the page limit, all the proofs are removed and are available from the authors upon request.

*The contract design problems*

Suppose that the type-$(j,k)$ sales agent has chosen a contract $(\alpha_t,\beta_t)$ by reporting $s_A=t$. Let $N_{jk}\equiv\mathbb{E}[\theta|s_A=j,s_R=k]$ be the sales agent's belief on the expected market condition. Then the profit-maximizing sales agent chooses his sales effort $a$ to solve

$$\mathcal{A}_{jk}(t)\equiv\max_{a\geq 0}\mathbb{E}\left[\alpha_t+\beta_t x-\frac{1}{2}a^2\middle| s_A=j,s_R=k\right]=\max_{a\geq 0}\alpha_t+\beta_t N_{jk}a-\frac{1}{2}a^2.$$

With the optimizer $a_{jk}^*(t)=N_{jk}\beta_t$, the resulting expected profit is $\mathcal{A}_{jk}(t)=\alpha_t+\frac{1}{2}\beta_t^2N_{jk}^2$. Let $\mathcal{A}_{jk}\equiv\mathcal{A}_{jk}(j)$ and $a_{jk}^*\equiv a_{jk}^*(j)$ be the sales agent's expected profit and effort under truth-telling.

Taking the sales agent's response into consideration, the type-$k$ reseller designs a compensations scheme $\{(\alpha_F,\beta_F),(\alpha_U,\beta_U)\}$ to maximize her own expected profit. As the reseller observes the demand signal $s_R=k$, she believes that $s_A=j$ with probability $P_{jk}\equiv\Pr(s_A=j|s_R=k)$. Moreover, because the menu should induce the type-$(j,k)$ sales agent to choose $(\alpha_j,\beta_j)$, we have $\mathbb{E}[x|s_A=j,s_R=k]=N_{jk}a_{jk}^*=N_{jk}^2\beta_j$. Suppose the reseller has chosen a contract $(u_t,v_t)$ by reporting $s_R=t$, she will then earn $u_t-\alpha_j+(v_t-\beta_j)N_{jk}^2\beta_j$ in expectation when the sales agent sees signal $s_A=j$. Therefore, the type-$k$ reseller solves

$$\mathcal{R}_k(t)\equiv\max_{\substack{\alpha_F\text{ urs.},\beta_F\geq 0,\\ \alpha_U\text{ urs.},\beta_U\geq 0}}\sum_{j\in\{F,U\}}P_{jk}\left[u_t-\alpha_j+(v_t-\beta_j)N_{jk}^2\beta_j\right] \tag{1}$$

$$\text{s.t.}\quad \mathcal{A}_{Fk}\geq 0,\mathcal{A}_{Uk}\geq 0 \tag{2}$$

$$\mathcal{A}_{Fk}\geq\mathcal{A}_{Fk}(U),\mathcal{A}_{Uk}\geq\mathcal{A}_{Uk}(F). \tag{3}$$

The objective function (1) is to maximize the reseller's expected profit (based on her own belief). The two individual rationality (IR) constraints in (2) guarantee a nonnegative expected payoff for both types of sales agent. The two incentive compatibility (IC) constraints in (3) ensure that both types of sales agent prefer the contract intended for them. Let $\mathcal{R}_k\equiv\mathcal{R}_k(k)$ be the reseller's expected profit under truth-telling. In the following lemma, we characterize the reseller's optimal menu.

**Lemma 1.** *If the reseller has observed the demand signal* $s_R=k\in\{G,B\}$ *and has chosen the contract* $(u_t,v_t)$, *it is optimal for her to offer* $\beta_F^*=v_t$ *and* $\beta_U^*=\frac{P_{Uk}}{P_{Uk}+P_{Fk}(N_{Fk}^2/N_{Uk}^2-1)}v_t\equiv Y_kv_t$ *to the sales agent. The reseller's expected profit is* $\mathcal{R}_k(t)=u_t+\frac{1}{2}Z_kv_t^2$, *where*

$$Z_k\equiv P_{Fk}N_{Fk}^2+\frac{P_{Uk}^2N_{Uk}^2}{P_{Uk}+P_{Fk}(N_{Fk}^2/N_{Uk}^2-1)}.$$

Now we consider the manufacturer's problem in designing the menu $\{(u_G, v_G), (u_B, v_B)\}$. Once the manufacturer sees that the contract $(u_k, v_k)$ is chosen, it knows that the reseller has observed $s_R = k$. In this case, the conditional expectation of sales is

$$\mathbb{E}[x|s_R = k] = \sum_{j\in\{F,U\}} P_{jk} a_{jk}^* = P_{Fk} N_{Fk}^2 v_k + P_{Uk} N_{Uk}^2 Y_k v_k = Z_k v_k \tag{4}$$

and the manufacturer's expected profit is $(1 - v_k) Z_k v_k - u\_k$. With our assumption $\gamma = \frac{1}{2}$, simple derivations show that the manufacturer will see each type of reseller with probability $\frac{1}{2}$. The manufacturer's contract design problem is thus formulated as

$$\mathcal{M} \equiv \max_{\substack{u_G \text{ urs.}, v_G \geq 0, \\ u_B \text{ urs.}, v_B \geq 0}} \sum_{k\in\{G,B\}} \frac{1}{2} [(1 - v_k) Z_k v_k - u_k] \tag{5}$$

$$\text{s.t.} \quad \mathcal{R}_G \geq 0, \qquad \mathcal{R}_B \geq 0, \tag{6}$$

$$\mathcal{R}_G \geq \mathcal{R}_G(B), \qquad \mathcal{R}_B \geq \mathcal{R}_B(G). \tag{7}$$

The two IR constraints in (6) guarantee the reseller's participation while the two IC constraints in (7) ensure truth-telling. The objective function (5) is to maximize the manufacturer's expected profit. The optimal solution to the manufacturer's problem is summarized in the following lemma.

**Lemma 2.** *It is optimal for the manufacturer to offer* $v_G^* = 1$ *and* $v_B^* = Z_B/Z_G$ *to the reseller. The manufacturer's expected profit under the optimal contract is* $\mathcal{M} = \frac{1}{4}[Z_G + Z_B^2/z_{\text{G}}]$. *The reseller receives* $\mathcal{R}_B = 0$ *if she observes a bad signal,* $\mathcal{R}_G = \frac{1}{2}(Z_G - Z_B)(Z_B^2/Z_G)^2$ *if she observes a good signal, and* $\mathcal{R} = \frac{1}{2}(\mathcal{R}_G + \mathcal{R}_B) = \frac{1}{4}(Z_G - Z_B)(Z_B/Z_G)^2$ *in expectation.*

Because resellers of different types will offer different contracts in equilibrium, we denote the contract intended for the type-$(j,k)$ sales agent as $(\alpha_{jk}^*, \beta_{jk}^*)$ in the sequel. Combining the above two lemmas, we have $\beta_{FG}^* = 1$, $\beta_{UG}^* = Y_G$, $\beta_{FB}^* = v_B^*$, and $\beta_{UB}^* = Y_B v_B^*$.

To facilitate the discussions below, we will refer to $v_B^*$ as the upstream distortion factor, which appears when the reseller observes a bad signal. Similarly, we refer to $Y_k$ as the downstream distortion factor, which is present when the sales agent observes an unfavorable signal. The smaller $v_B^*$ or $Y_k$ is, the larger distortion we have.

**Supply chain performance and the reseller's accuracy**

We start the discussion from the supply chain's perspective. To examine supply chain performance, we focus on the expected sales quantity $\mathbb{E}[x]$, as this represents the total revenue generated by the supply chain. The analysis starts from demonstrating its convexity in the following proposition. Figure 1 illustrates one particular example, in which the expected sales is *nonmonotone*: it is first decreasing and then increasing as the reseller improves her forecasting accuracy. Most of the parameter combinations result in the same nonmonotonicity.

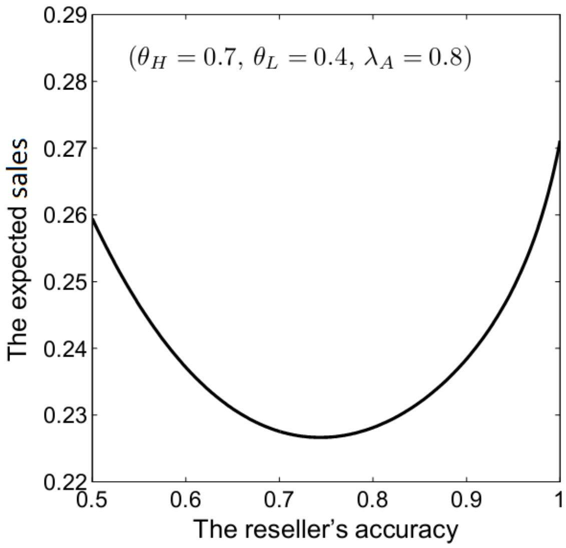


*Figure 1 – Nonmonotonicity of the expected sales.*

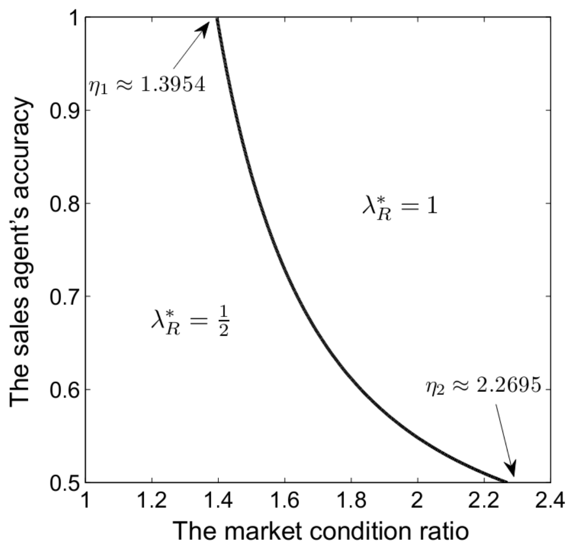


*Figure 2 – System-optimal reseller's accuracy.*

**Proposition 1.** *The expected sales* $\mathbb{E}[x]$ *is convex on* $\lambda_R \in \left[\frac{1}{2}, 1\right]$.

The above proposition as well as our numerical experiments show that typically the expected sales decreases in the reseller's accuracy when the accuracy is low but increases when the accuracy is high. As we explain in detail below, improving the forecasting accuracy creates two different effects in our three-layer supply chain. How does the reseller's accuracy affect the expected sales then depends on the relative importance of these effects.

Improving the reseller's accuracy first introduces the conventional better-monitoring effect. As the reseller can better estimate the market condition, she can better infer the sales effort and design a more accurate compensation scheme. This will induce the sales agent to exert a higher sales effort and eventually result in a higher sales in expectation. To understand this effect, recall that the downstream distortion factor $Y_k$ depends on $N_{Fk}^2/N_{Uk}^2 - 1$ (cf. Lemma 1), the degree of adverse selection in the reseller-agent relationship. Because the reseller sees the good signal and the bad signal with the same probability, the overall effect of adverse selection is captured by $\frac{1}{2}(N_{FG}^2/N_{UG}^2 - 1) + \frac{1}{2}(N_{FB}^2/N_{UB}^2 - 1)$, the expected degrees of adverse selection. It can then be verified that $N_{FG}^2/N_{UG}^2 + N_{FB}^2/N_{UB}^2$. In short, the better-monitoring effect reduces the lower-level information asymmetry and brings benefits to the supply chain.

Now we turn to the manufacturer-reseller relationship. Because the manufacturer is always uninformed, improving the reseller's accuracy unambiguously aggravates the information asymmetry between the manufacturer and reseller. As the reseller's signal $s_R$ becomes more informative, she is able to earn a larger information rent upon observing a good signal. In order to pay fewer rents, the manufacturer has the incentive to cut down the bonus for the reseller observing the bad signal (note that $Z_F$ increases in $\lambda_R$, $Z_U$ decreases in $\lambda_R$, and thus $v_U^*$ decreases in $\lambda_R$). This rent-extraction effect then allows the manufacturer to better differentiate different reseller types and extract more rents. Nevertheless, it also aggravates the upstream distortion, creates additional efficiency loss, and drives down the effort level as well as the sales outcome in expectation.

In summary, the better-monitoring and rent-extraction effects together decide the shape of the expected sales as a function of the reseller's accuracy. When the accuracy is low and the information asymmetry between the manufacturer and reseller is small, any accuracy improvement enlarges the manufacturer's informational disadvantage substantially. In other words, the rent-extraction effect is strong. At the same time, the accuracy improvement only helps the reseller resolve a relatively small part of her informational disadvantage; this suggests that the better-monitoring effect is weak. Therefore, the rent-extraction effect is dominant in the supply chain and the expected sales decreases when the reseller improves her

accuracy. On the contrary, if the reseller has already been highly accurate, in most cases the negative rent-extraction effect will be only marginal while the positive better-monitoring effect is more significant. Supply chain performance is thus improved when the reseller further improves her high accuracy.

Finally, we note that the manufacturer's expected profit $\mathcal{M}$ is exactly one half of the supply chain's expected sales revenue.

**Lemma 3.** $\mathcal{M} = \frac{1}{2}\mathbb{E}[x]$.

Lemma 3 immediately implies that the manufacturer may be hurt when the reseller improves her accuracy. If the manufacturer is allowed to decide the reseller's accuracy (e.g., by choosing the appropriate reseller to delegate to), it will maximize the expected sales by making the reseller either uninformed or precise.

**System-optimal reseller's accuracy and supply chain structure**

As we have established in Proposition 1, the expected sales $\mathbb{E}[x]$ is convex on $\lambda_R \in \left[\frac{1}{2}, 1\right]$. Therefore, from the supply chain's perspective, the supply chain should include either the uninformed reseller with $\lambda_R = \frac{1}{2}$ or the precise reseller with $\lambda_R = 1$. Because the reseller in our supply chain does nothing but demand forecasting, including the uninformed reseller is equivalent to operating a direct supply chain with only the manufacturer and the sales agent.

Therefore, our analysis in this section also allows us to determine whether the direct supply chain outperforms the indirect one.

We state our main result regarding the system-optimal reseller's accuracy in the following proposition. Let $\lambda_R^* \equiv \text{argmax}_{\lambda_R \in [1/2,1]} \mathbb{E}[x]$ be the system-optimal reseller's accuracy. As we demonstrate in the next proposition, $\lambda_R^*$ is determined by the market condition ratio $\eta$ and the sales agent's accuracy $\lambda_A$.

**Proposition 2.** *Let $\eta_1 \approx 1.3954$ be the unique greater-than-one root of $\eta^5 - \eta^4 - 2\eta^2 + \eta = -1$ and $\eta_2 \approx 2.2695$ be the unique greater-than-one root of $\eta^4 - 2\eta^3 - \eta^2 = -2$. Then (1) for $\eta \in (1, \eta_1)$, $\lambda_R^* = \frac{1}{2}$ for all $\lambda_A$; (2) for $\eta \in [\eta_1, \eta_2]$, there exists a unique $\bar{\lambda}_A(\eta) \in \left[\frac{1}{2}, 1\right]$ such that $\lambda_R^* = \frac{1}{2}$ if $\lambda_A < \bar{\lambda}_A(\eta)$, $\lambda_R^* = 1$ if $\lambda_A > \bar{\lambda}_A(\eta)$, and $\lambda_R^* = \{\frac{1}{2}, 1\}$ if $\lambda_A = \bar{\lambda}_A(\eta)$; and (3) for $\eta \in (\eta_2, \infty)$, $\lambda_R^* = 1$ for all $\lambda_A$.*

We visualize the above proposition in Figure 2, in which $\bar{\lambda}_A(\eta)$ is illustrated by the curve as a function of $\eta$ on the interval $[\eta_1, \eta_2]$. $\lambda_R^*$ is different in the two regions separated by the curve. The first determinant of $\lambda_R^*$ is the market condition ratio $\eta \equiv \theta_H/\theta_L$. Recall that $\theta_H$ and $\theta_L$ are the two possible realizations of $\theta$, the random market condition. When $\eta < \eta_1$, the difference between $\theta_H$ and $\theta_L$ is small, and naturally the benefit of distinguishing the two realizations is only marginal: A wrong estimate does not deviate from the actual state too much. Therefore, the strength of the precise reseller is limited and the uninformed reseller is preferred. When $\eta < \eta_2$, the result is opposite and the precise reseller is preferred. This is because distinguishing the two quite different realizations now becomes more valuable.

The problem is more interesting when $\eta$ is moderate, i.e., between the two cutoffs. To understand how the sales agent's accuracy makes an influence, it is easier to treat including the uninformed reseller as operating a direct supply chain and consider whether to include the precise reseller. While the main benefit of including the reseller is brought by the better-monitoring effect, the rent-extraction effect creates efficiency loss. Because the rent-extraction effect appears in the manufacturer-reseller relationship, it harms the supply chain in the same way regardless of the sales agent's accuracy. On the contrary, the amount of benefits generated by the better-monitoring effect critically depends on how accurate the sales agent is. When the sales agent is highly accurate, the manufacturer must find a way to mitigate the information asymmetry. This is why it should include the reseller for indirect monitoring. As we observe in Figure 2, when the sales agent becomes more accurate (i.e., when $\lambda_A$ increases), the range of $\eta$ for the indirect supply chain to be preferred (i.e., $\lambda_R^* = 1$) enlarges. This verifies the above intuitive arguments.

## Conclusion

In this paper, we consider a three-layer supply chain with a manufacturer, a reseller, and a sales agent. While the manufacturer is uninformed about the realization of the random market condition, both the reseller and the sales agent can conduct demand forecasting to estimate the realized market condition. We show that supply chain performance as well as the manufacturer's profitability are hurt when the reseller or the sales agent improves her/his low accuracy. When the accuracy is high, however, an improvement may enhance supply chain performance and allow the manufacturer to earn more in expectation. From the supply chain's and the manufacturer's perspectives, when the market condition ratio and the sales agent's forecasting accuracy are both low, the uninformed reseller is preferred; when these two parameters are both high, delegating to the precise reseller is optimal.

## References


Cachon, G., M. Fisher. 2000. Supply chain inventory management and the value of shared information. *Management Science* **46**(8): 1032–1048.

Cederlund, J.P., R. Kohli, S.A. Sherer, Y. Yao. 2007. How Motorola put CPFR into action. *Supply Chain Management Review* **11**(7): 28–35.

Chen, Y.J., W. Xiao. 2012. Impact of reseller's forecasting accuracy on channel member performance. *Production and Operations Management.* **21**(6): 1075–1089.

Fraser, J. 2003. CPFR - Status and perspectives. D. Seifert, ed., *Collaborative Planning, Forecasting, and Replenishment: How to create a supply chain advantage.* Amacon, New York, USA, 70–93.

Gavirneni, S., R. Kapuscinski, S. Tayur. 1999. Value of information in capacitated supply chains. *Management Science* **45**(1): 16–24.

Lee, H., C. So, C. Tang. 2000. The value of information sharing in a two-level supply chain. *Management Science* **46**(5): 626–643.

Maskin, E., J. Tirole. 1992. The principal-agent relationship with an informed principal: The case of private values. *Econometrica* **58**(2): 379–409.

Masking, E., J. Tirole. 1992. The principal-agent relationship with an informed principal, ii: Common values. *Econometrica* **60**(1): 1–42.

Miyaoka, J., W.H. Hausman. 2008. How improved forecasts can degrade decentralized supply chains. *Manufacturing & Service Operations Management* **10**(3): 547–652.

Shin, H., T. Tunca. 2010. The effect of competition on demand forecast investments and supply chain coordination. *Operations Research* **58**(6): 1592–1610.

Stoller, J. 2004. Tooloing up: Supply chain optimizaion. *Purchasing B2B* **6**(4): 20–24.

Taylor, T., W. Xiao. 2010. Does a manufacturer benefit from selling to a better-forecasting retailer? *Management Science* **56**(9): 1584–1598.