Strategic procurement from forward contract and spot market

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Abstract
Purpose – The purpose of this paper is to formulate procurement strategies and determine the optimal procurement quantity in order to maximize profit through forward contracting and the spot market.

Design/methodology/approach – The procurement process is modeled at various stages along a time horizon from the perspective of the buyer, with consideration of uncertain yields, stochastic demand and dynamic spot market prices. Monte Carlo simulation based experiments were conducted to figure out the best procurement quantity for five different scenarios. The framework was developed to understand the impact of different uncertain variables on a firm’s profit. A case study was carried out in a steel making company in India, with real data.

Findings – The results indicate that the proposed approach enables buyers to achieve higher profits under volatile demand conditions. In the case study, it was found that the profit is higher for the spot market than for contract pricing if there is significant demand and spot price volatility.

Originality/value – This research considers not only demand uncertainty but also supply uncertainty in the procurement process, and profit analysis was carried out to enable an enterprise to set up a procurement plan by using forward contracting and the spot market. This study should also increase awareness in both academia and industry on the opportunities of using the spot market to enhance flexibility and to mitigate risk in the procurement process.

Keywords Procurement, Uncertainty, Forward contract, Monte Carlo simulation, Spot market

1. Introduction
Procurement is the combination of different methods for purchasing goods, services or work from an external source in order to fulfill targeted activities. It includes many participants (e.g. suppliers, buyers, customers) and involves many variables such as demand, supply and price. The combination of the above-mentioned variables and participants, leads to procurement decisions, as well as different degrees of collaboration in the supply chain, and therefore influences the management of risk. It is, clearly, more favorable if items are procured at the best price and meet the needs in terms of quality and quantity, time and location (Van Weele, 2001), under conditions of

This work is supported by the Hong Kong Polytechnic University. The authors’ gratitude is also extended to the research committee and the Department of Industrial and Systems Engineering of the Hong Kong Polytechnic University for support in this project.
scarcity and uncertainty. According to Chambers and Quiggin (2000), uncertainty is defined as a state where there is limited knowledge for describing exactly an existing situation or future outcome. It is measured by the assigned probabilities of each possible state or outcome. From the perspective of uncertainty in the procurement process, there are two major uncertainties: demand uncertainty and supply uncertainty. Demand uncertainties arise from four sources: data on past and present markets (Carlton and Dana, 2004), problems with forecasting techniques (Ilmakunnas, 1996), supply chain unpredictability (Lee, 2002) and environment changes (Basu et al., 2008). Similarly, the factors that affect supply uncertainties in procurement can be categorized into: environmental conditions, delivery constraints, logistics conditions and globalization.

Portfolio procurement has a significant impact on risk allocation and influences decisions in the subsequent supply chain management. A long-term contract with a fixed price can shift more risk and responsibility to the contractor than a short-term contract with a fluctuating price (Floricel and Miller, 2001). In contrast, purchasing raw material from the spot market can shorten the lead time and avoid backlog at the expense of higher cost. In the meanwhile, the extra raw material can be sold back to the spot market and save inventory costs to some extent. Previous studies have shown how to control the risk, under either demand uncertainties or supply uncertainties, with different procurement strategies (Chen and Liu, 2007; Inderfurth and Kelle, 2011; Spindler and Huchzermeier, 2006), and how their combinations affect the supply chain performance (He and Zhao, 2012). There are, however, few investigations that focus synthetically on both demand and supply uncertainties from the buyer perspective. Adoption of the spot market as a procurement strategy to cope with disruption risks motivates us to realize the possibility of including spot purchases together with forward contracts. The aim of this study, therefore, is to investigate how to quantify portfolio procurement so as to maximize the profit for buyers. The scope of this study is mainly concerned with the single period procurement problem of a single item in the presence of the spot market.

2. Literature review
2.1 Overview of supply chain risk management (SCRM)
Risk in the supply chain appears as any event that might affect the movement of materials, all the way from the initial suppliers to the final customers, and disrupt the planned flow of materials. In practice, there are many types of risk in the supply chain, either from internal or external sources, ranging from minor inconveniences to the complete destruction of the supply chain.

The whole SCRM process starts with risk identification of the source of problems, the assessment and ranking of the identified risks, and ends with deciding how to respond to these risks. The techniques to manage the potential risks fall into four major categories: avoidance, reduction, transfer and retention (Dorfman and Cather, 1994). The pioneering works of Hau Lee have proved that proper information transfer (Lee et al., 2004), information sharing as well as order postponement (Chen and Lee, 2009) will improve the supply chain performance. However, these works were conducted from the perspective of demand only.

2.2 Demand uncertainty and supply uncertainty in procurement
As procurement covers the flow of materials or services from the provider to the purchaser, procurement risks belong to the strategic risks of the broad risk portfolio
Moreover, in terms of the overall impact, procurement risks fall into the category of high probability of occurrence and severe loss. Therefore, great effort should be placed to manage procurement risks in the supply chain. Prior research on the SCRM in procurement has examined how these uncertainties impact on the procurement decision. For example, Erhun et al. (2008) examined the effect of dynamic pricing as a mean to deal with the risks in the supply chain. They found that the introduction of additional demand information does not always benefit the buyer as the suppliers can use the demand data and receive procurement quantities in the first period so as to adjust the prices in the second stage. Furthermore, when the supplier controls the production capacity as well as the prices, dynamic pricing is the best alternative for all parties, including the end customers. Mukhopadhyay and Ma (2009) used a two-stage analysis to determine the yield rate of used parts. The procurement and production quantities were determined with more information, so as to retain the risks associated with demand uncertainty and ambiguity. Few papers consider procurement management under supply uncertainty. Only Xu and Lu (2013) studied the effect of supply chain uncertainty on the optimal order quantity, and they found that under a cost structure for both the in-house production case and the procurement case, a less variable yield rate led to a lower optimal price and a higher expected profit. Taking both demand and supply uncertainties into consideration, the supply environment incorporated quantity and timing uncertainty, and the demand uncertainty was illustrated in terms of a quasi-concave distribution (Bollapragada et al., 2004). However, the work was conducted from the aspect of the supplier and the focus was placed on inventory control rather than procurement.

2.3 Risk sharing through portfolio procurement
Portfolio procurement means that the buyer can have a long-term contract, option contract or spot market (Fu et al., 2010). The long-term contract shifts the risk of cost overrun because the quantities and prices of raw material to be purchased are predetermined. In addition, more specific rules such as product specification, delivery pattern and estimated arrival time are made. At the same time, buyers can get the same raw material from the spot market with unlimited supply and varying prices. In the study conducted by Chen and Liu (2007), numerical analysis was carried out to develop the procurement strategies for a buyer with demand uncertainty. A similar problem was also analyzed by researchers (Inderfurth and Kelle, 2011; Inderfurth et al., 2013; Zhang et al., 2011) using joint procurement sources. However, in these papers, the spot market only functions as a sourcing channel for raw material and the research does not extend the function of the spot market in reselling the excess raw material.

Our paper addresses the more realistic issue of procurement by allowing buyers to resell the raw material back to the spot market. We also address the necessity of taking both demand uncertainty and supply uncertainty into consideration at the same time.

3. Model structure
A model of a single period supplier-buyer procurement system was developed such that the buyer orders products from the contract supplier and allows the buyer to determine whether the raw material is processed to finished the goods or the raw material is sold back to the spot market. From the demand point of view, it is assumed that the buyer should decide on the purchase volume from the supplier before the
selling season starts. Because of the long lead time of the purchased items, the buyer is not able to replenish the inventory and process the raw materials during the selling season. Such circumstance settings are widely accepted for model building in supply chain contracts (Akella et al., 2005; Chen and Liu, 2007; Seifert et al., 2004; Yano and Lee, 1995). Without loss of generality, the numerical equations discussed below assume that the customer demand \( X \) and spot price \( P \) (for both the buying side and the selling side) follow a uniform distribution (i.e. \( X \sim U[\mu_X - \sigma_X/2, \mu_X + \sigma_X/2] \), \( P \sim U[\mu_P - \sigma_P/2, \mu_P + \sigma_P/2] \)). Therefore, closed-form solutions can be obtained. Under a completely competitive consumer market, the sale price is constant in this study. Furthermore, the capacity and storage in the factory will not act as a decision factor so the buyer’s purchasing decision of the forward contract is independent of the inventory problem. Given the fact that the buyer has the same information in regard to the spot price distribution, the buyer would place the same value on the regular supply contract. The above settings of the demand side follow the work of Chen and Liu (2007).

From the supply side, because of the existence of the yield uncertainty in the supply, the delivered amount \( Y \) is the product of a random variable \( y \) and the ordered amount \( Q \) (Agrawal and Nahmias, 1997; Federgruen and Yang, 2009). In the analyzed model, it is assumed that there are two supply options that the buyer can consider at different stages: Option 1, the buyer selects a contract supplier who provides raw materials at lower cost with fixed unit price \( W \) and known long lead time, at time \( T_1 \). In addition, this contract supplier is subject to yield risk \( y \); Option 2, the buyer uses the spot market with essentially negligible lead time but stochastic spot price. The buyer can also combine these two options. At time \( T_1 \), the buyer decides on the contract amount \( Q \) with Option 1. Later, at time \( T_2 \), demand for the finished product and the uncertain yield of the raw material are recognized. Processing is completed at time \( T_3 \), and the buyer has to decide whether to sell the remaining raw material to the customer or the spot market; at what price and in what quantity. The detailed decision process of the buyer is described in Figure 1 (Table I).

4. Model formulation

Given both demand and supply uncertainties, the procurement problem is formulated in terms of five scenarios, according to the existence of the contract and the spot market, and their corresponding development conditions. The optimum decisions of the quantities for procurement are found. Figure 2 illustrated those circumstances in terms of cash, material and order flows.

Figure 1. Decision process of the buyer
In each case, the background is set to be the same as that in the work of Chen and Liu (2007) and Nagurney (2010): the buyer orders \( Q \) units from the supplier at price \( W \) at time \( T_1 \). At time \( T_2 \), the demand for the finished product is realized, and \( Y \) units are delivered. The buyer needs to make further decisions based on the current information, such as the realized demand, units delivered and spot market prices. Then the buyer processes \( Y \) units and sells them to the customers. When the spot market exists, if the delivered volume \( Y \) is more than the demand \( X \), the buyer can sell the extra units to the spot market at price \( P_s \) at time \( T_3 \); or if the delivered volume \( Y \) is less than the demand \( X \), the buyer can purchase the needed units \( (X - Y) \) from the spot market as raw material at price \( P_b \) at time \( T_2 \). However, this is not the preferred option because the long lead time will leave insufficient time to process the raw material before the selling season. Therefore, the buyer can choose to buy \( (X - Y) \) units of raw material from the selling side spot market at time \( T_2 \) at price \( P_s \) to fulfill the demand. When the retail price \( R \) is higher than \( P_s \), the buyer can still earn some profit through selling the extra raw material in the spot market. Otherwise, when \( P_s \) exceeds \( R \), the buyer will lose money in selling the products in the spot market. The combination of the contract and the spot market, by considering the spot market price at the buying side or the selling side, leads to five feasible scenarios. The equations for the combined profit function are adopted from and the basic forms are described in Chen and Liu (2007) and Hong and Lee (2013).

4.1 Scenario A: a fully developed contract market without spot market

In this case, the spot market is absent. Therefore, the buyer can neither sell the extra raw material to the spot market nor purchase finished products from the spot market to fulfill the demand. The overall profit is made from the \( Y \) units and \( (X - Y) \) units of order are lost. The profit function is described as:

\[
\Pi = \begin{cases} 
RX + S(Y - X) - WY, & X < Y \\
RY - WY, & X \geq Y 
\end{cases}
\]

(A)

4.2 Scenario B: a fully developed spot market without contract market

In this case, the contract market is absent while the spot market is completely developed both on the selling side and the buying side. Therefore, the entire
Buying and selling processes take place via the spot market. The profit function is described as:

$$\Pi = \begin{cases} 
P_s X + P_{bT2} (Y - X) - P_{bT1} Y, & X < Y \\
P_s Y - P_{bT1} Y, & X \geq Y 
\end{cases}$$

Notes: (a) Scenario A: a developed contract market without spot market; (b) Scenario B: a fully developed spot market without contract market; (c) Scenario C: a developed contract market but with spot market only in the buy side; (d) Scenario D: a developed contract market but with spot market only in the sell side; (e) Scenario E: a fully developed contract market and spot market on both the buy and sell side.
4.3 Scenario C: a developed contract market but with spot market only in the buying side
In this case, the contract market is fully developed and the spot market is partly developed in the buying side, so the buyer can purchase more raw materials from the spot market and cannot sell the extra raw material to the spot market. The profit function is described as:

\[ \Pi = \begin{cases} RX + P_b(Y - X) - WY, & X < Y \\ RY - WY, & X \geq Y \end{cases} \]  

(C)

4.4 Scenario D: a developed contract market with spot market in the selling side only
In this case, the contract market is fully developed and the spot market is partly developed in the selling side, so the buyer cannot purchase extra raw materials but can sell the excess raw material to the spot market. The profit function is described as:

\[ \Pi = \begin{cases} RX + P_s(Y - X) - WY, & X < Y \\ RX - P_s(Y - X) - WY, & X \geq Y, P_s < R \\ RY - WY, & X \geq Y, P_s \geq R \end{cases} \]  

(D)

4.5 Scenario E: a fully developed contract market and spot market on both the buy and sell side
In this case, both the contract market and the spot market are fully developed. The buyer has the freedom to arrange the procurement and production processes to the most convenient extent. The profit function is described as:

\[ \Pi = \begin{cases} RX + P_s(Y - X) - WY, & X < Y \\ RX - P_s(X - Y) - WY, & X \geq Y, P_s < R \\ RY - WY, & X \geq Y, P_s \geq R \end{cases} \]  

(E)

The first equation describes the situation where the buyer resells the excess ordered \((Y - X)\) raw material back to the spot market at price \(P_s\) on the selling side. In addition, the second equation described the buyer purchase \((X - Y)\) units of raw material from the spot market to fulfill the demand when the retail price is higher than the spot market price. The third equation illustrates the net profit when the spot price is higher than the retail price.

5. Case study
In this section, an empirical investigation is undertaken by conducting a case study in a steel making company and applying Monte Carlo simulation for the five scenarios. Data has been taken from Rajasthan Wires Pvt Ltd which operates in Kolkata, the eastern hub of steel making in India. This company has two running mills with a combined output of 1,000 ton on average per month. Mild Steel Angle and Mild Steel Flat Plate are its main products, while channels, TMT and Round Mild Steel are also produced. As our research group can provide potentially free consultation, the case company is open and willing to share the challenges faced. The case study lasted for ten months, from August 2010 to May 2011. The reasons for selecting the simulation model were: first, simulations can help in cases where the system involves uncertainty. The procurement in the SCRM involves stochastic demand and supply. In such cases,
simulation can be applied to gain information about the supply chain process. Second, simulation makes model rebuilding and testing more time saving and economical. The production environment of the company is a combination of assemble-to-order and make-to-order. Therefore, various types of raw materials, mainly iron ore or coal, and common standard components, are kept in stock and the production only starts when the demand is confirmed. The main output is mild steel which can be further processed into other products. In order to cope with the fluctuation of the raw material prices, the company tends to use the spot market without conventional contracts. As the raw material of the steel and the steel products can be sold to the end customers or the spot market, the situation is represented as Scenario B.

5.1 Case study (Scenario B)
Based on collection of practical data from August 2011 to January 2012, as shown in Tables II-IV, the simulations were run 100 times, each time with 1,000 trials. In the case study, steel was used as an example and a normal distribution was adopted based on the research studies of GE and various scholars (He et al., 2012; Yang et al., 2012; GE Commercial Finance, 2007).

<table>
<thead>
<tr>
<th>Year: 2011 month</th>
<th>Average purchase price (in S$)</th>
<th>STD of purchase price (in S$)</th>
<th>Average quantity bought (in ton)</th>
<th>STD of quantity bought (in ton)</th>
<th>Average selling price (in S$)</th>
<th>STD of selling price (in S$)</th>
<th>Average quantity sold (in ton)</th>
<th>STD of quantity sold (in ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 2011</td>
<td>835.28</td>
<td>11.57</td>
<td>34</td>
<td>23</td>
<td>925.80</td>
<td>13.61</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>September 2011</td>
<td>820.56</td>
<td>4.97</td>
<td>33</td>
<td>19</td>
<td>917.87</td>
<td>7.36</td>
<td>32</td>
<td>20</td>
</tr>
<tr>
<td>October 2011</td>
<td>847.17</td>
<td>9.18</td>
<td>31</td>
<td>22</td>
<td>962.90</td>
<td>21.85</td>
<td>23</td>
<td>13</td>
</tr>
<tr>
<td>November 2011</td>
<td>876.00</td>
<td>13.90</td>
<td>41</td>
<td>23</td>
<td>972.16</td>
<td>13.95</td>
<td>28</td>
<td>15</td>
</tr>
<tr>
<td>December 2011</td>
<td>877.84</td>
<td>12.58</td>
<td>36</td>
<td>23</td>
<td>980.80</td>
<td>13.98</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>January 2012</td>
<td>893.75</td>
<td>4.91</td>
<td>38</td>
<td>21</td>
<td>1,014.14</td>
<td>8.87</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>Mean</td>
<td>858.43</td>
<td>9.52</td>
<td>36</td>
<td>22</td>
<td>962.28</td>
<td>13.27</td>
<td>27</td>
<td>15</td>
</tr>
</tbody>
</table>

Table II. Collected data with regard to price and quantity

<table>
<thead>
<tr>
<th>Variables</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand</td>
<td>X</td>
<td>27</td>
</tr>
<tr>
<td>Mean</td>
<td>( \mu_X )</td>
<td>15</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>( \sigma_X )</td>
<td>( 0.1 )</td>
</tr>
<tr>
<td>Random yield</td>
<td>y</td>
<td>0.85</td>
</tr>
<tr>
<td>Mean</td>
<td>( \mu_y )</td>
<td>( 0.1 )</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>( \sigma_y )</td>
<td>0.1</td>
</tr>
<tr>
<td>Spot market price (buy side)</td>
<td>( P_b )</td>
<td>S$858</td>
</tr>
<tr>
<td>Mean</td>
<td>( \mu_{pb} )</td>
<td>S$858</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>( \sigma_{pb} )</td>
<td>$10</td>
</tr>
<tr>
<td>Spot market price (sell side)</td>
<td>( P_s )</td>
<td>S$962</td>
</tr>
<tr>
<td>Mean</td>
<td>( \mu_{ps} )</td>
<td>S$962</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>( \sigma_{ps} )</td>
<td>$13</td>
</tr>
</tbody>
</table>

Table III. Input data for the simulation
The results are illustrated in Figure 3 and show that the optimal purchasing quantity is 68 units when the procurement strategy can earn S$2,800 profit.

Taking the mean profit per unit sold to be S$102.65, it can be calculated that 27 units (2,800/102.65) can be sold, the same as the mean quantity sold over a period of six months. Therefore, the model is proven to be accurate and dependable. In addition, the extra 41 units (the difference between the optimal purchasing quantity and the sold quantity) can be kept as safety stock to cope with the high demand variability and random yield of the delivered order. Moreover, as the raw material can be sold back to the spot market, the company can either get salvage value from the spot market or keep the extra stock for the next manufacturing process.

<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
<th>Inserted formulae</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot market price (buy side) at $T_1$</td>
<td>$P_{bT1}$</td>
<td>$\text{PsiNormal}(858,10)$</td>
<td>867.73</td>
</tr>
<tr>
<td>Spot market price (buy side) at $T_2$</td>
<td>$P_{bT2}$</td>
<td>$P_{bT1} \times \text{PsiNormal}(1,0.05)$</td>
<td>837.13</td>
</tr>
<tr>
<td>Quantity</td>
<td>$Q$</td>
<td>$\text{PsiSimParam}(1,100)$</td>
<td>100.00</td>
</tr>
<tr>
<td>Random yield</td>
<td>$y$</td>
<td>$\text{PsiNormal}(0.05,0.1)$</td>
<td>0.78</td>
</tr>
<tr>
<td>Delivered units</td>
<td>$Y$</td>
<td>$Q \times y$</td>
<td>78.19</td>
</tr>
<tr>
<td>Demand</td>
<td>$X$</td>
<td>$\text{PsiNormal}(27,15)$</td>
<td>36.42</td>
</tr>
<tr>
<td></td>
<td>$P_s$</td>
<td>$\text{PsiNormal}(962,13)$</td>
<td>956.51</td>
</tr>
</tbody>
</table>

Table IV.
Sample values for the simulation

The results are illustrated in Figure 3 and show that the optimal purchasing quantity is 68 units when the procurement strategy can earn S$2,800 profit.

Taking the mean profit per unit sold to be S$102.65, it can be calculated that 27 units (2,800/102.65) can be sold, the same as the mean quantity sold over a period of six months. Therefore, the model is proven to be accurate and dependable. In addition, the extra 41 units (the difference between the optimal purchasing quantity and the sold quantity) can be kept as safety stock to cope with the high demand variability and random yield of the delivered order. Moreover, as the raw material can be sold back to the spot market, the company can either get salvage value from the spot market or keep the extra stock for the next manufacturing process.
5.2 Sensitivity analysis
Sensitivity analysis can help to assess the robustness of the proposed model. Ferson and Tucker (2006) investigated how the inputs influence the results of the model. Figure 4(a) shows the extent to which a variable has an impact on the final results. Generally, the analysis is carried out based on the relationship between the demand amount \( X \) and the true delivery amount \( Y \). The red column or line indicates the

\[
\begin{align*}
\text{(a)} & \quad P_{bT_1} \quad 0.804 \quad 0.503 \\
\text{(b)} & \quad \text{Spot Market (buy side) at } T_1 \text{ vs Profit}
\end{align*}
\]

\[
\begin{align*}
\text{(c)} & \quad \text{Spot Market (buy side) at } T_2 \text{ vs Profit}
\end{align*}
\]

\[
\begin{align*}
\text{(d)} & \quad \text{Demand vs Profit}
\end{align*}
\]

\[
\begin{align*}
\text{(e)} & \quad \text{Random variable } y \text{ vs Profit}
\end{align*}
\]

\[
\begin{align*}
\text{(f)} & \quad \text{Spot Market (sell side) at } T_3 \text{ vs Profit}
\end{align*}
\]

Notes: (a) Selected variables; (b) effect of spot market price (buy side) at \( T_1(P_{bT_1}) \) on profit; (c) effect of spot market price (buy side) at \( T_2(P_{bT_2}) \) on profit; (d) effect of demand on profit; (e) effect of random yield on profit; (f) effect of spot market price (sell side) at on profit at \( T_3(P_s) \) on profit

Figure 4. Sensitivity analysis result
condition of the profit changes when \( X < Y \), while the blue column or line indicates the profit changes when \( X \geq Y \). To be specific, the quantity for testing was set as 25 for \( X < Y \) and 68 for \( X \geq Y \). In Figure 4(a), it is clear that the variables of the spot market price (buying side) \( P_{bT1} \) and demand \( X \) have the most significant influence on the decision for the optimal purchase quantity and the maximum profit.

In Figure 4(b), the effect of \( P_{bT1} \) on the profit is shown when the mean value is increased from S$700 to S$900. The more the increase in the mean spot market price, the less the profit is. However, the slope of the red line \((X < Y)\) is much greater than that of the blue line \((X \geq Y)\). This is because, for the case of \( X \geq Y \), the profit equation is \( \Pi = (P_s - P_{bT1}) \times Y \) instead of \( \Pi = P_s \times X + (Y - X) \times P_{bT2} - P_{bT1} \times Y \). So, as long as \( P_{bT1} \) increases, the profit per unit decreases much faster than that of the case where \( X < Y \).

Figure 4(c) illustrates a different situation. When the demand is less than the delivery amount \((X > Y)\), the profit increases linearly, as long as the spot market price on the buying side increases at time \( T_2 \) and the profit remains unchanged when \( X \geq Y \). This is because of the long lead time of production, so it is impossible for the buyers to book and receive the raw material at time \( T_2 \) when they find that the actual delivery amount is less than ordered. Thus, what buyers can do is to only sell the extra raw materials at a price that is much lower than the initial ordered price and suffer a loss beyond the intersection point \( P_{bT2} = S$770 \).

With regard to the effect of the demand on the profit, the values of the demand were increased from ten to 50 units and their corresponding changes on the profit were recorded, as shown in Figure 4(d). It is observed that when there is less demand than the delivered amount \((X < Y)\), the profit increases linearly with the increased demand value. This is because, when demand increases, the buyer is capable of selling more products and getting more profit. Since the delivered goods \( Y \) are always more than the demand \( X \), the buyer is able to fulfils the market demand. Therefore higher demand is favorable for the buyer. On the other hand, in the situation of an inadequate delivered amount \((X \geq Y)\), the profit increases linearly before the saturation point \((X = 22 \text{ units})\) and then remains constant after that. This situation occurs because the buyer cannot fulfill the demand beyond the delivered amount. Thus, the profit remains unchanged, irrespective of the demand value increase. The overlapping curves indicate the same effect of demand on the profit, whatever customer demand is satisfied.

Referring to the effect of random yield on the profit, it is easy to understand that when the demand amount is less than the actual delivered amount \((X < Y)\), the buyer can only keep the profit at a constant level of S$2,800, with a mean of \( P_{bT1} \) and \( P_{bT2} \) of S$858. While for the case of \( X \geq Y \), the profit increases and the yield increases. In addition, the gap between these two lines indicates the capability of the buyer in selling extra goods. These attributes are fully illustrated in Figure 4(e).

The effect of the spot market (selling side) at \( T_3(P_s) \) on the profit is shown in Figure 4(f). With \( P_s \) increased from S$900 to S$1,100, the profits correspondingly increased in both cases. However, the slope in case \( X < Y \) is much steeper than that in case \( X \geq Y \). The steeper slope indicates the greater effect of yield on the profit.

5.3 Results on other scenarios

To test the performance of the proposed model in other scenarios, simulations were conducted according to the data in the Table V.

Referring to each scenario, there are some interesting findings. First in Scenario A, the profit function illustrates a reversed U shape (Figure 5) and the overall profit is
<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
<th>Scenario A</th>
<th>Scenario C</th>
<th>Inserted formulae</th>
<th>Scenario D</th>
<th>Scenario E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales price</td>
<td>$R$</td>
<td>962</td>
<td>1,100</td>
<td>1,100</td>
<td>1,100</td>
<td>1,100</td>
</tr>
<tr>
<td>Wholesale price</td>
<td>$W$</td>
<td>858</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>Salvage price</td>
<td>$S$</td>
<td>600</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Quantity</td>
<td>$Q$</td>
<td>$\text{PsiSimParam}(1,50)$</td>
<td>$\text{PsiSimParam}(1,100)$</td>
<td>$\text{PsiSimParam}(1,75)$</td>
<td>$\text{PsiSimParam}(1,75)$</td>
<td>$\text{PsiSimParam}(1,75)$</td>
</tr>
<tr>
<td>Random yield</td>
<td>$Y$</td>
<td>$\text{PsiNormal}(0.85,0.1)$</td>
<td>$\text{PsiNormal}(0.85,0.1)$</td>
<td>$\text{PsiNormal}(0.85,0.1)$</td>
<td>$\text{PsiNormal}(0.85,0.1)$</td>
<td>$\text{PsiNormal}(0.85,0.1)$</td>
</tr>
<tr>
<td>Delivered units</td>
<td>$Y$</td>
<td>$y \times Q$</td>
<td>$y \times Q$</td>
<td>$y \times Q$</td>
<td>$y \times Q$</td>
<td>$y \times Q$</td>
</tr>
<tr>
<td>Demand</td>
<td>$X$</td>
<td>$\text{PsiNormal}(27,15)$</td>
<td>$\text{PsiNormal}(27,15)$</td>
<td>$\text{PsiNormal}(27,15)$</td>
<td>$\text{PsiNormal}(27,15)$</td>
<td>$\text{PsiNormal}(27,15)$</td>
</tr>
<tr>
<td>Spot market price (buy side)</td>
<td>$P_b$</td>
<td>/</td>
<td>$\text{PsiNormal}(858,10)$</td>
<td>/</td>
<td>$\text{PsiNormal}(858,10)$</td>
<td>$\text{PsiNormal}(858,10)$</td>
</tr>
<tr>
<td>Spot market price (buy side)</td>
<td>$P_s$</td>
<td>/</td>
<td>/</td>
<td>$\text{PsiNormal}(962,13)$</td>
<td>$\text{PsiNormal}(962,13)$</td>
<td>$\text{PsiNormal}(962,13)$</td>
</tr>
<tr>
<td>$X &lt; Y$</td>
<td>Case 1</td>
<td>$R \times X + S \times (Y - X) - W \times Y$</td>
<td>$R \times X + P_b \times (Y - X) - W \times Y$</td>
<td>$R \times X + P_s \times (Y - X) - W \times Y$</td>
<td>$R \times X - P_s \times (Y - X) - W \times Y$</td>
<td>$R \times X - P_s \times (Y - X) - W \times Y$</td>
</tr>
<tr>
<td>$X \geq Y$</td>
<td>Case 2</td>
<td>$P_r &lt; R \times Y - W \times Y$</td>
<td>$(R - W) \times Y$</td>
<td>$IF(X &lt; Y, Case1, Cases2)$</td>
<td>$IF(P_r &lt; R, Case2, Case3)$</td>
<td>$IF(P_r &lt; R, Case2, Case3)$</td>
</tr>
<tr>
<td></td>
<td>Case 3</td>
<td>$P_s \geq R$</td>
<td>/</td>
<td>$IF(X &lt; Y, Case1, Cases2)$</td>
<td>$IF(P_s &lt; R, Case2, Case3)$</td>
<td>$IF(P_s &lt; R, Case2, Case3)$</td>
</tr>
<tr>
<td>Profit</td>
<td>Profit</td>
<td>$IF(X &lt; Y, Case1, Cases2 and 3)$</td>
<td>$IF(P_r &lt; R, Case2, Case3)$</td>
<td>$IF(P_s &lt; R, Case2, Case3)$</td>
<td>$IF(P_s &lt; R, Case2, Case3)$</td>
<td>$IF(P_s &lt; R, Case2, Case3)$</td>
</tr>
<tr>
<td>Average profit</td>
<td>Avg_Profit</td>
<td>$\text{PsiMean (profit)}$</td>
<td>$\text{PsiMean (profit)}$</td>
<td>$\text{PsiMean (profit)}$</td>
<td>$\text{PsiMean (profit)}$</td>
<td>$\text{PsiMean (profit)}$</td>
</tr>
<tr>
<td>Optimum quantity</td>
<td>$Q^*$</td>
<td>27 units/days</td>
<td>33 units/days</td>
<td>43 units/days</td>
<td>43 units/days</td>
<td>43 units/days</td>
</tr>
<tr>
<td>Max profit</td>
<td>$\Pi^*$</td>
<td>$S$1,750</td>
<td>$S$1,250</td>
<td>$S$1,990</td>
<td>$S$1,990</td>
<td>$S$1,990</td>
</tr>
</tbody>
</table>
much lower than that in the case study. The reason lies in the absence of the spot market. When the procurement is carried out without the involvement of the spot market, the buyer can only get the salvage price (considerably less than the original cost) for the extra ordered goods instead of selling them at the regular market price. Therefore, the buyer would not like to take the risk of ordering extra quantities and may lose some orders. A similar situation can also be found for Scenario C (Figure 6) where the procurement is done with only the spot market on the buying side.

Second, another set of inputs \( R = \$962 \) and \( W = \$858 \), while the other parameters were kept constant) was additionally tested for Scenario C. The simulated result showed that the optimal ordered quantity of 74 units can bring in \$2,800 profit, and the distribution is illustrated in Figure 7. It is easy to find that the maximum profit is the same as that of the case study while the required quantity (74 units) is slightly higher than that in the case study (68 units). The difference is because of the instability of the spot market.

Third, the distribution of the profit function in Scenario D (Figure 8) is exactly the same as that of Scenario E. This is because of the almost similar input in the model so that another set of inputs \( R = \$962 \) and \( W = \$858 \), while other parameters were kept constant) was used to test Scenario E, and the result is shown in Figure 9. Both the required quantity and maximum profit in Figure 8 are much less than that of the case study. The loss was generated by selling the extra units at a lower profit margin. When the possibility of loss is higher, the buyer is less likely to order higher quantities. In addition, when the ordered quantity is more than the optimal amount, the buyer will suffer losses and that is why the profit function has in an inverted U shape.
With regard to another set of inputs for Scenario E, the results in Figure 9 illustrate that when the new sale price and wholesale price are set to be equal to the mean values of the spot market prices on the buying side and selling side, respectively, the buyer will not suffer any loss for the extra goods. Therefore, the buyer will earn more for...
further orders and that is the reason for the linear profit function. However, this situation does not reflect practical cases.

Regarding the concept validity, the mean profit per unit sold is S$102.65 units, as shown in Table VI, then the units sold would be $\frac{2,800}{102.65} = 27$ units
The mean quantity sold over the period of six months, as shown in Table II, is also 27. This proves that the model is accurate and dependable as it takes into account the average demand facing the firm and other variables in the optimum procurement strategy. The seemingly high extra units ($68 - 27 = 41$ units) act as safety stock for three main purposes.

In general, a time series based on a sequence of evenly spaced monthly or yearly data points come up with different forecasting results. Unlike the bubbles in financial market assets, commodities such as steel and copper, incur storage and shipping costs and have a certain supply base that cannot rapidly expand, and the material needs to be consumed after production (Vogel, 2010). Therefore, if a merchandiser makes a procurement decision based on the actual needs rather than acting as leveraged speculation, the price will be more stable. However, as mentioned by Vogel (2010), the high expectation of continuing price rises leads to herd behavior, and may lead to over valuation compared to past historical prices which in turn leads to price surges. However, once pessimistic news emerges, it may induce collapse and bubble bursting.

6. Conclusions
The spot market emerged several decades ago and research on spot markets, especially for electricity, oil and some commodities, still continues. The spot market can help to enrich a contract portfolio by mitigating risk so as to optimize the profit. When raw material has high price volatility, spot purchasing can play a proactive role for procurement risk management. The spot market, which rethinks the contract design from a postponement point of view, is ripe for new insights in contract portfolios and supply contract valuation.

Consideration of both demand and supply uncertainties as well as the involvement of the contract and spot market has resulted in successful problem solving and profit maximization according to the simulation results. The proposed model improves the conventional way of procurement planning, which is normally based on estimation and experience. It allows users to simply choose scenarios which best suit their industry and then input the values of the variables to find the optimal solutions. Analysis of the results demonstrated that the involvement of the spot market can bring in more profit than a pure contract approach if there is significant demand and spot price volatility.

The results from this study reveal several practical applications worthy of future study. First, it would be valuable to further examine how to simulate the distributions of the demand and the spot price and how they impact on each other. This study assumed that the demand and the spot price are independent and known to the buyer.

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean profit per unit (in S$)</th>
<th>Standard deviation of profit (in S$)</th>
<th>CV of profit (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 2011</td>
<td>87.88</td>
<td>19.00</td>
<td>22</td>
</tr>
<tr>
<td>September 2011</td>
<td>97.60</td>
<td>23.00</td>
<td>24</td>
</tr>
<tr>
<td>October 2011</td>
<td>111.79</td>
<td>25.00</td>
<td>22</td>
</tr>
<tr>
<td>November 2011</td>
<td>96.50</td>
<td>20.00</td>
<td>21</td>
</tr>
<tr>
<td>December 2011</td>
<td>101.83</td>
<td>29.00</td>
<td>28</td>
</tr>
<tr>
<td>January 2012</td>
<td>120.30</td>
<td>21.00</td>
<td>17</td>
</tr>
<tr>
<td>Mean for six months</td>
<td>102.65</td>
<td>23.00</td>
<td>22</td>
</tr>
</tbody>
</table>

Table VI. Profit variability of the company
In practice, the demand and the spot price may be correlated and the correlation should be handled in advance to dampen any adverse effects. Therefore, the data collection and simulation is crucial. Second, an area that deserves immediate attention is to extend the single period analysis into multiple-period patterns. In the proposed model, buyers were assumed to be risk-neutral. This assumption can be revised when the buyers may tend to be risk-averse in multiple periods of time. Third, incorporating financial derivatives into the model could enhance the application in practical situations. In practice, buyers need to consider the opportunity cost whenever hoarding is happening. To conclude, this study has paved the way for formulating sourcing strategies by combining the spot market and forward contracting with consideration of demand and supply uncertainty. Future research should study how the demand and supply variables affect sourcing decisions at different stages.

References


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