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1 > 2? Less is more under volatile exchange rates in global supply chains

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Abstract To meet consumer needs, global firms typically manufacture based on their aggregate production plan after receiving demand projections from all markets. One of the consequences of matching demand with manufacturing is that these plans generally ignore the impact of exchange rate fluctuations. Consolidated profits for global firms are significantly influenced by fluctuations in exchange rates, and opportunity exists to incorporate exchange rate uncertainty into global production planning. This article presents an operational hedging mechanism ('production hedging') based on manufacturing *less* than the total global demand. Due to uncertainty in exchange rates, the firm takes conservative action and deliberately manufactures a smaller quantity than its total global demand. The article shows how manufacturing less can create a higher profit. It provides prescriptions for marketing executives to quantify the economic value of market share. In addition, it demonstrates why operational hedging, in the form of production hedging, is more valuable than financial hedging.

1. Introduction

In October 2011, the U.S. dollar hit its lowest level against the Japanese yen since the Great Depression. Japanese firms that manufacture in Japan and rely on revenues generated through sales in the United States were hit hard by the U.S. dollar depreciation; Toyota Motor Company is an example, with considerable manufacturing activities still taking place in Japan and a significant level of revenues generated in the U.S. It is commonly reported that consolidated profits of multinational firms are impacted by fluctuations in foreign currencies. Our work responds to the challenges of these global firms by offering a different perspective that incorporates exchange rate fluctuations into manufacturing and distribution plans.

Since the early 1990s, U.S. firms have shown interest in expanding their market reach and global revenues by increasing distribution and sales in Southeast Asia. These U.S. firms experienced significant losses when, in 1997, the Thai baht was devaluated and took down other Asian currencies (e.g., Malaysian ringgit, Indonesian rupiah, Korean won, Philippine peso, Japanese yen). Similar currency devaluations have proven detrimental, including the Mexican peso devaluation (1994),

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the Russian ruble crisis (1998), the Brazilian real collapse (1999), and the Turkish lira losses (1994 and 2001). Recent economic uncertainty—including the U.S. credit crisis (2008) and European economic instability exhibited by Spain (2012), Greece (2012), and Cyprus (2013)—further increases global firms' desire to guard against exchange rate uncertainty. Speculation persists regarding the true value of the Chinese renminbi (RMB); numerous studies have attempted to explain the RMB exchange rate (see Yi, 2013). Given the financial and economic instability surrounding our world, Lyles and Park (2013) emphasize the importance of a profitable growth in the lifecycle of internationalization. Our work provides prescriptions for this important problem as it helps explain the implications of currency fluctuations in supply chain planning.

Traditional aggregate planning activities call for demand projections from multiple markets. Large multinational companies collect demand forecasts from their subsidiaries in foreign countries. These demand forecasts are usually entered through an enterprise resource planning (ERP) application, and central planning/headquarters makes the appropriate procurement and production commitments based on these forecasts. In general, firms combine demand forecasts from multiple markets and commit to manufacturing for the total global demand. Such plans typically ignore potential swings in currencies, and rather rely on the expected value of foreign currencies. Our work shows that this traditional practice of building manufacturing activities in order to match the global demand has significant exchange rate uncertainty implications.

Why should an operations manager in charge of supply chain planning worry about fluctuations in exchange rates? After all, business professionals are trained via educational programs based on widely separate curriculums. While myriad sources support the separation of financial and operational concerns, the most influential explanation comes from Modigliani and Miller (1958). These authors argue that, under certain assumptions, financial and operational decisions can be separated; therefore, an operations manager should not be concerned about the risk stemming from financial markets. Expanding upon this, Caldentey and Haugh (2006) and Sun, Wissel, and Jackson (2013) conclude that a firm can make its operational plans by isolating itself from financial market uncertainty—including exchange rate fluctuations.

The featured approach in this study, however, differs from the aforementioned perspective of separating the worries associated with financial market swings from supply chain planning. We show that an operations manager, especially when she commits to manufacturing the global demand in her aggregate production plan, can be highly impacted by exchange rate fluctuations. Therefore, we recommend that an operations manager incorporate exchange rate uncertainty in supply chain planning. Based on Kazaz, Dada, and Moskowitz (2005), our work belongs to a different stream of publications whereby exchange rate and financial market fluctuations influence the firm's operational decisions. This stream of research includes Huchzermeier and Cohen (1996); Dasu and Li (1997); Lowe, Wendell, and Hu (2002); Ding, Dong, and Kouvelis (2007); and Park, Kazaz, and Webster (2014a and 2014b).

To mitigate the negative implications of exchange rate fluctuations, our work recommends the concept of *production hedging*: a deliberate decision on the part of the firm to manufacture less (i.e., smaller quantity) than its total demand. Production hedging is a conservative action of the operations manager who is concerned about exchange rate fluctuations, and mimics the concept of less-is-more. Our work demonstrates that by manufacturing a smaller quantity than its total demand, the firm creates the flexibility to alter its distribution of products to markets based on changes in exchange rates. According to this approach, the firm allocates manufactured goods to markets where the currency is appreciating, thus enjoying higher returns; it concurrently slashes allocation to markets where the currency is depreciating, thus avoiding lessened revenues or even losses. It is important to note that the same distribution allocation flexibility cannot be created when the firm engages in the traditional practice of manufacturing the total demand. Thus, unlike the popular approach of matching demand, our work proposes creating flexibility in distribution operations in order to respond to the changes in financial markets.

2. Is 1 truly greater than 2?

To demonstrate the impact of exchange rate uncertainty on a global firm's profit, we develop a small example with only three exchange rate scenarios. This example incorporates exchange rate uncertainty into the firm's aggregate production planning activities; the mathematical model that serves as the foundation of the notion of $1 > 2$ is outlined in the Appendix.

The firm determines a quantity of products to manufacture in the presence of exchange rate uncertainty; we consider the common event that manufacturing lead times are long enough that the firm has to commit to production levels in the presence of exchange rate uncertainty. After observing the realized (spot) values of exchange rates, the firm determines how to allocate the amount manufactured to various markets. We assume that transportation lead times are sufficiently short to alter allocation decisions based on the realized exchange rates. Long manufacturing lead times with short transportation lead times are commonly observed in industries such as electronics and apparel.

Stage 1: The firm determines the optimal manufacturing quantity that maximizes its expected global profit under exchange rate uncertainty.

Stage 2: After observing the realized value of the random exchange rates, the firm determines the optimal amount of stock to be allocated to each market, subject to the constraint that the total amount allocated to markets in Stage 2 cannot exceed the amount manufactured in Stage 1.

Next, we provide an example to demonstrate how less can be more under exchange rate uncertainty.

2.1. Example

We consider a firm that manufactures a product in the United States and sells it in two markets: the U.S. and Europe. Manufacturing in the United States is not a necessary assumption; the production activity can take place elsewhere. Because the manufacturing costs are paid in advance of sales revenue, it can be assumed that the manufacturing expense is paid at the spot exchange rate when the production decision takes place.

Costs: We consider two types of costs: manufacturing and transportation (including duties, localization, et cetera). The firm manufactures a product at \$90/unit in the United States. The firm incurs a transportation cost of \$5/unit to distribute the product to its customers in the U.S., and similarly, \$5/unit to ship to its customers in Europe.

Selling price: The selling price of the product is \$100/unit in the United States and €100/unit in Europe.

Demand: To present the benefits of producing less than the total demand, we consider the event that demand in the United States is 1 unit and demand in Europe is 1 unit. Thus, the firm has a total global demand of 2 units. We analyze whether the firm will make more money when it manufactures 2 units—that is, its total demand—or 1 unit as part of its production hedging policy. Is 1 greater than 2? Actual demand numbers can be substituted into the same analysis; naturally, they would increase the dollar impact of the profits and make our conclusions more pronounced. We provide a numerical illustration from a U.S. manufacturer with unequal demand values in Section 2.2.

Exchange rate uncertainty: The revenues generated through sales in Europe, denominated in the local currency of euros, get converted to the U.S. dollar using the exchange rate. Let us assume that the euro-to-dollar exchange rate, designated as \$/€, is expected to be 1; that is, each euro in revenue is expected to be equal to one dollar. However, this conversion rate can fluctuate. We consider a simplified example with three scenarios in order to walk through the numerical calculations (Table 1).

According to Table 1, the euro-to-dollar exchange rate (\$/€) can take the following three scenarios: (1) the euro depreciates to \$0.50/€ with probability 0.40, (2) the value stays at the equal value of \$1.00/€ with probability 0.20, or (3) the euro appreciates to \$1.50/€ with probability 0.40. Given these three scenarios and their associated probabilities, the expected value of the euro-to-dollar exchange rate is:

Expected value of \$/€ = (\$0.50/€) (0.40)
+ (\$1.00/€) (0.20) + (\$1.50/€) (0.40) = 1.00

It is important to remember that the firm manufactures in the presence of exchange rate uncertainty and pays the manufacturing cost in U.S. dollars. After observing the realized exchange rate, the firm collects revenues from sales in Europe in euros and from sales in the United States in dollars. The revenues generated in euros are converted back to the U.S. dollar with the realized exchange rate.

Profit margins: Given the cost and price information, it can be easily said that the firm is expected to make profits in each of the two markets. For each unit manufactured with the goal to be sold in a specific market, the profit margin can be calculated as follows:

Profit margin in a market
= Selling price × Exchange rate
− transportation cost − manufacturing cost.

Table 1. Exchange rate scenarios used in the example

Scenario	€-to-\$ exchange rate (\$/€)	Associated Probability
Scenario 1: Euro depreciates	\$0.50/€	0.40
Scenario 2: Euro stays constant	\$1.00/€	0.20
Scenario 3: Euro appreciates	\$1.50/€	0.40

Following this approach,

Profit margin in the U.S. =
$100 (selling price) − $5 (transportation cost) − $90 (manufacturing cost) = $5 > 0.

Profit margin in Europe =
€100 (selling price) × $1/€ (expected exchange rate) − $5 (transportation cost) − $90 (manufacturing cost) = $5 > 0.

When averaged across three scenarios, the firm has profitable sales in both markets, and is expected to make $5 in each market. When using expected value of the exchange rate, both markets are equally profitable. Thus:

Economic value of each market in the absence of exchange rate uncertainty = $5.

Traditional aggregate plans that utilize ERP solutions generally ignore exchange rate fluctuations. These ERP-based aggregate plans would call for the manufacturing of the total global demand corresponding to the recommendation that the production amount should equal 2 units.

2.1.1. How much money can be made by manufacturing the total demand?

We next evaluate the firm's expected profit when it manufactures the total demand of 2 units. The firm pays the following manufacturing cost upfront for the production of 2 units:

Manufacturing cost = − $90/unit × 2 units manufactured = $180.

Now that the firm has 2 products, let us consider how it would distribute its products and collect its revenues under each scenario.

Scenario 1 (euro depreciates to $0.50/€)

Revenue in the U.S. = $100 (selling price) − $5 (transportation cost) = $95 > 0.

Revenue in Europe = €100 (selling price) × $0.50/€ (realized exchange rate) − $5 (transportation cost) = $45 > 0.

The firm obtains a positive revenue from both markets, albeit the U.S. market revenue is higher than that of the European market. Because the manufacturing costs are already paid and correspond to sunk costs at this stage, the firm would try to get the highest revenues from its sales. This would indicate that it sells its product in each of the markets and satisfies the global demand.

Revenue from the U.S. = $95 × 1 unit of demand satisfied = $95

Revenue from Europe = $45 × 1 unit of demand satisfied = $45

Total revenue from Scenario 1 = $140.

Scenario 2 (euro is $1.00/€)

Revenue in the U.S. = $100 (selling price) − $5 (transportation cost) = $95 > 0.

Revenue in Europe = €100 (selling price) × $1.00/€ (realized exchange rate) − $5 (transportation cost) = $95 > 0.

Both markets provide the same return. Once again, the firm would sell 1 unit in each market.

Revenue from the U.S. = $95 × 1 unit of demand satisfied = $95

Revenue from Europe = $95 × 1 unit of demand satisfied = $95

Total revenue from Scenario 2 = $190.

Scenario 3 (euro appreciates to $1.50/€)

Revenue in the U.S. = $100 (selling price) − $5 (transportation cost) = $95 > 0.

Revenue in Europe = €100/unit (selling price) × $1.50/€ (expected exchange rate) − $5 (transportation cost) = $145 > 0.

The firm obtains a positive return from both markets, albeit the revenue from the European market is higher than that of the U.S. market. Regardless, the firm would sell 1 unit in Europe and 1 unit in the U.S., and satisfy its global demand.

Revenue from the U.S. = $95 × 1 unit of demand satisfied = $95

Revenue from Europe = $145 × 1 unit of demand satisfied = $145

Total revenue from Scenario 3 = $240.

The expected profit from producing and satisfying the global demand can be calculated by taking the total revenues from each scenario, multiplying them with their associated probabilities, and subtracting the upfront manufacturing cost. Thus:

Expected profit from manufacturing the total demand

= − \$180 (manufacturing cost)
+ \$140 × 0.40 (revenue from Scenario 1 × Scenario 1 probability)
+ \$190 × 0.20 (revenue from Scenario 2 × Scenario 2 probability)
+ \$240 × 0.40 (revenue from Scenario 3 × Scenario 3 probability)
= \$10.

These calculations demonstrate that when the firm follows the traditional practice of producing according to the total demand, it would generate an expected profit of \$10. This expected profit corresponds exactly to the same value that the firm anticipated as its profit using the expected value of the exchange rate. Thus, it can be concluded that when the firm matches demand with its production, incorporating exchange rate uncertainty into the analysis does not make an impact.

It is important to note that half of this consolidated profit, corresponding to \$5, is generated from sales in Europe (the uncertain market) and the other half of \$5 from sales in the U.S. Thus:

Economic value of each market in the presence of exchange rate uncertainty = \$5.

Consider a scenario in which the manager is given additional flexibility to not serve one of her/his two markets. This unserved market could be either the U.S. market or the European market. Given that the European market presents the only risky market with uncertain conversion values of sales revenues, let us focus on the European market. We ask the simple question: What would be the economic value of not serving the European market prior to observing the exchange rate uncertainty? We have already established the economic value of the European market as \$5 both under the expected value of the exchange rate and under exchange rate uncertainty. Indeed, when managers are asked to associate the perceived value of the market share in a specific market, they tend to designate it with the economic value as calculated above, and demand to be compensated for \$5. Thus, a manager's perceived value of market share in a market can be considered as \$5, equivalent to the economic value that can be gained from that market. This value becomes beneficial when we discuss the pros and cons of not serving all markets in Section 3.

2.1.2. How much money can be made with production hedging?

The general intuition is that producing less leads to smaller profits. We next evaluate the firm's expected profit under the conservative approach of manufacturing less than the total demand. Under production hedging, we consider manufacturing the demand of only one of the two markets. Thus, the firm manufactures only 1 unit, which is less than its total global demand of 2 units. Does 1 generate a higher expected profit than 2? The firm pays the following manufacturing cost upfront for the production of 1 unit:

Manufacturing cost = − \$90/unit × 1 unit manufactured = \$90.

Production hedging creates the flexibility to alter distribution based on the realized values of exchange rates at the expense of starving some markets. Let us determine the firm's preference of allocation to markets and the corresponding revenues under each exchange rate scenario.

<u>Scenario 1 (euro depreciates to \$0.50/€)</u>

Revenue in the U.S. = \$100 (selling price) − \$5 (transportation cost) = \$95/unit > 0.

Revenue in Europe = €100 (selling price) × \$0.50/€ (realized exchange rate) − \$5/unit (transportation cost) = \$45 > 0.

The firm experiences a higher profit margin in the U.S. than Europe; therefore, it is best to allocate the product to the U.S. market.

Revenue from the U.S. = \$95 × 1 unit = \$95

Revenue from Europe = \$45 × 0 units = \$0

Total revenue from Scenario 1 = \$95.

<u>Scenario 2 (euro is \$1.00/€)</u>

Revenue in the U.S. = \$100 (selling price) − \$5 (transportation cost) = \$95 > 0.

Revenue in Europe = €100 (selling price) × \$1.00/€ (expected exchange rate) − \$5 (transportation cost) = \$95 > 0.

In this scenario, both markets exhibit the same level of revenues, and therefore the firm is indifferent between the two markets. Let us consider selling the product in the United States; it is important to note that, with actual demand values, the firm can adjust its allocation in a way that it serves both markets partially.

Revenue from the U.S. = \$95 × 1 unit = \$95

Revenue from Europe = \$95 $\times$ 0 units = \$0

Total revenue from Scenario 2 = \$95.

Scenario 3 (euro appreciates to \$1.50/€)

Revenue in the U.S. = \$100 (selling price) − \$5/unit (transportation cost) = \$95/unit $>$ 0.

Revenue in Europe = €100 (selling price) $\times$ \$1.50/€ (expected exchange rate) − \$5 (transportation cost) = \$145 $>$ 0.

The firm experiences a higher revenue in Europe; therefore, it prefers to sell its product in the European market.

Revenue from the U.S. = \$95 $\times$ 0 units = \$0

Revenue from Europe = \$145 $\times$ 1 unit = \$145

Total revenue from Scenario 3 = \$145.

The expected profit from manufacturing only 1 unit—that is, production hedging—can be calculated by taking the total revenues from each scenario, multiplying them with their associated probabilities, and subtracting the upfront manufacturing cost. Thus:

Expected profit from production hedging

= − \$90	(manufacturing cost)
+ \$95 $\times$ 0.40	(revenue from Scenario 1 x Scenario 1 probability)
+ \$95 $\times$ 0.20	(revenue from Scenario 2 x Scenario 2 probability)
+ \$145 $\times$ 0.40	(revenue from Scenario 3 x Scenario 3 probability)
= \$25.	

It can be seen that manufacturing 1 unit generates a higher value of expected profit (\$25) than manufacturing the total global demand of 2 units (\$10). Thus, production hedging—more than manufacturing to the total global demand—leads to higher expected profit. Is 1 greater than 2? Certainly, manufacturing less leads to a higher expected profit as demonstrated in this example.

Here, production hedging also generates two-and-a-half times the profit of the total demand; alternatively, production hedging brings 150% more profit than producing to the total demand. Next, we present a numerical analysis using data from an actual U.S. manufacturer.

2.2. The case of a U.S. manufacturer

We now consider a single product of a U.S. manufacturer. The global demand for this particular product can be divided into three regions, where (1) the United States generates 50%, (2) the European market generates 15%, and (3) the Asian market—primarily sales in Japan—generates 35%. Exchange rate data consists of daily real exchange rates from January 1, 2009, to December 31, 2011, with 752 observations. The mean and standard deviation of the daily real exchange rates are provided in Table 2.

Table 2. Mean and standard deviation of daily real exchange rates

	\$/€	\$/¥
Mean	1.370845	0.011556
Standard deviation	0.068097	0.000887

The selling price of this product is \$100 in the United States, €73 in Europe, and ¥8,654 in Japan; it complies with the anti-dumping laws, as sales in all regions return equal values at the expected values of the exchange rates. The firm reports a unit manufacturing cost of \$97.90 and transportation costs of \$1.15 (to the U.S.), \$1.16 (to Europe), and \$1.18 (to Japan). The firm operates with thin margins; however, all three markets are profitable, even when all possible exchange rate scenarios are aggregated. Thus, a traditional aggregate plan would recommend manufacturing 100% of the firm's global demand.

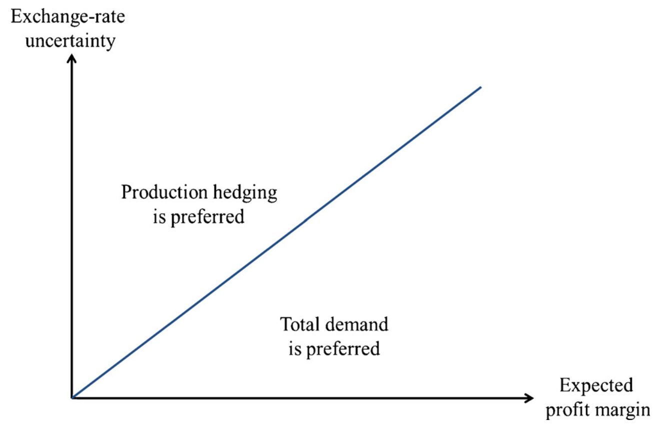
Considering all possible scenarios results in six potentially optimal manufacturing policies based on various percentages of the firm's global demand. These six potentially optimal policies consist of manufacturing 15%, 35%, 50%, 65%, 85%, and 100% of the total demand. It is important to observe that two different combinations, one from the U.S. market and another from the sum of the demand values from the European and Asian markets (15% + 35%), result in the same policy of 50%; otherwise, the firm would have to consider additional policies. Let us begin with the traditional practice of manufacturing the total demand, and scale the expected profit to \$1.

The optimal manufacturing quantity in this problem turns out to be 65% of the firm's global demand. Using the same scale, the firm would make \$2.09 when it manufactures 65% of its global demand. This would mean that the firm manufactures less and yet makes 109% more on its expected profit. Thus, less is more! It should be noted here that by giving up 35% of its market share, the firm can generate up to \$1.09 over the profit from 100% of its total demand.

2.3. Drivers of production hedging

We have illustrated that production hedging, as opposed to the traditional practice of matching

Figure 1. Production hedging versus total demand preference of the firm under increasing values of exchange rate uncertainty and expected profit margin



the total demand, leads to higher expected profits. But what conditions drive production hedging to be more beneficial for a global firm? Considering our setting with long manufacturing lead times and short transportation lead times, production hedging becomes desirable under the following two conditions: (1) volatile exchange rates and/or (2) low profit margins. When exchange rates exhibit significant volatility, even reasonable profit margins can quickly erode during downswings, resulting in losses rather than expected profits. And when the firm has a relatively high sourcing cost (i.e., the sum of manufacturing and transportation costs) or a low selling price, its small profit margins will always be subject to the threat of becoming losses, even with the smallest of reductions in exchange rates. Figure 1 demonstrates the firm's preference between manufacturing the total demand versus implementing a production hedging policy based on increasing exchange rate uncertainty and expected profit margins.

It is important to highlight that in the examples developed earlier, production hedging is preferred because of relatively high manufacturing costs. These examples feature small transportation costs; however, production hedging is even more desired when the firm has relatively high transportation costs, even if the manufacturing costs are small (e.g., bulky, commodity-type products). This is because when the foreign currency depreciates significantly, the revenue from the foreign market may not justify the transportation cost. The firm may not be willing to move the product to the market in such foreign currency depreciations. This behavior is termed 'allocation hedging,' and is more likely to occur when transportation costs are relatively high. Because allocation hedging triggers additional reasons to not manufacture the total demand, higher transportation costs make the notion of 1 > 2 even more pronounced.

3. The economic value of market share

One of the consequences of production hedging is that the firm does not serve all of its markets and that some markets can starve for products. A chief marketing officer (CMO) may be upset with the fact that production hedging leads to intentional loss of market share. Is it ever ideal for a firm to give up its market share? If so, under what circumstances should this be tolerated? What option value of the flexibility to not serve each market—and thereby commit to a loss of market share—is necessary to persuade a CMO to sell less?

Production hedging is at odds with the notion of manufacturing for demand. For mature and commodity-type products, trying to match demand with supply—in this case, manufacturing—is not necessarily the best strategy. This is because the firm's commitment to serving the global market in its entirety eliminates the flexibility to serve appreciating markets while undercutting markets that are not likely to provide profitable sales. Thus, for these products, production hedging demonstrates that the flexibility to not serve at least some of the markets has a significant value.

In Section 2.1.1., we showed that the firm earns an expected profit of $5 from the U.S. market and another $5 from the European market. We have already established that a manager's perceived value of each market is typically $5, the amount equivalent to the economic value gained from each market. In order to evaluate the option value of the flexibility to not serve a market, let us first pay the firm's manager $5 upfront in order to have the flexibility to not serve at least one of its markets. Recall that production hedging leads to a profit of $25. Even if we pay the manager $5 for this additional flexibility, the remaining $20 is still greater than the $10 profit we would have generated by satisfying the total global demand. Therefore, we can conclude that the option value of the flexibility to not serve a market can be higher than the perceived and economic value of the present market share. The option value of the flexibility to not serve all markets can be evaluated as follows:

The option value of the flexibility to not serve all markets

= Expected profit from production hedging − Perceived value of total market share

= $25 − $5 (perceived value of the U.S. market) − $5 (perceived value of the European market)

= $15.

The CEO and/or CMO of a global firm might still argue that the strategic value of the market share might be higher than the economic value portrayed in this example. To be precise, the perceived value of the market share, which is a subjective evaluation, can be higher than its economic value ($5 for each market). Nonetheless, the calculation for the option value of the flexibility to not serve a market still provides an insightful comparison for CEOs and CMOs. If the sum of the differences between the perceived value and the economic value of each market exceeds $15, then the firm can manufacture its total global demand. However, it is important to note that most executives, in the absence of the production hedging policy, would not declare perceived values that are distinctly and significantly higher than the economic value of the markets they serve. Thus, the sum of the differences between the perceived value and the economic value of each market does not generally exceed $15 to eliminate production hedging. Considering that higher volatility in exchange rates generates significant option value for the flexibility to not serve a market, production hedging continues to be a viable policy even when marketing executives perceive the firm's market share in each market to be higher than its economic benefits.

3.1. What about serving markets partially?

Production hedging can starve some markets completely. Executives, on the other hand, might consider some market share to be strategic in order to establish the firm as a legitimate player in the market. Our analysis can be extended to require the firm to satisfy at least a certain percentage of its demand in each market. In this case, the expected value of the firm will be greater than $10, but less than $25. The firm continues to practice production hedging, but does not materialize the flexibility to alter its distribution allocation fully under this restriction.

Is there an economic value to this restriction of satisfying at least a certain percentage of market demand? Consider the same example we provided earlier, and let us extend the model by requiring that the firm must satisfy at least 20% of its market demand. Notice that in Scenarios 1 and 3—depreciation and appreciation of the Euro, respectively—the firm satisfies 20% of the unit demand in the less desirable market.

Under this restriction, if the firm continues to manufacture 1 unit, committing to production hedging, its expected profit becomes $17. To see how we arrive at $17, observe that in Scenario 2, the profits are equal in both markets, and there is no financial impact. However, in Scenario 1, the 20% restriction causes the firm to divert some of its allocation from the profitable U.S. market to Europe, causing a loss of 20% × ($95 − $45) = $10. Similarly, in Scenario 3, the 20% restriction causes the firm to divert some of its allocation from the highly profitable European market to the less profitable U.S. market, causing a loss of 20% × ($145 − $95) = $10. Because Scenarios 1 and 3 are likely to occur with 40% chance, a 20% demand satisfaction requirement has the following economic cost:

Economic loss from satisfying 20% of the market demand in each market

= + $10 × 0.40	(loss from Scenario 1 × Scenario 1 probability)
+ $0 × 0.20	(loss from Scenario 2 × Scenario 2 probability)
+ $10 × 0.40	(loss from Scenario 3 × Scenario 3 probability)
= $8.	

Economic profit with the restriction to satisfy 20% of market demand

= Expected profit from production hedging

− Expected loss from satisfying 20% of market demand

= $25 − $8 = $17.

Increasing the minimum requirement from 20% to higher levels yields greater economic loss for the firm. Thus, higher required levels of minimum demand further dampen the firm's expected profits.

3.2. What about the chief operating officer?

The chief operating officer (COO) of the global firm can also disfavor production hedging because it leads to under-utilized capacity. When optimal, production hedging provides several important indicators to COOs. It shows that the firm's total sourcing cost may be too high when compared with the selling price, leading to small profit margins. Given this relatively high cost structure, the firm cannot afford to target satisfying the global demand under exchange rate uncertainty. In other words, production hedging tells COOs not to build production capacity as fast as demand. In the previously noted cases, the flexibility to not serve some of the markets provides a significant value. The appropriate question for a COO becomes whether the firm can reduce its total sourcing cost fast enough to create a higher profit margin and service its global demand entirely.

Cost reductions generally take a long time to realize. Any adjustments in production, distribution, and logistical plans do not happen immediately, but both occur and pay off over time. Thus, squeezing additional pennies out of the cost structure is difficult to accomplish in short time periods. Once again, for these products, production hedging may be the only viable alternative.

4. Can financial hedging eliminate production hedging?

Production hedging leads to manufacturing less than the firm's global demand. One naturally wonders whether financial hedging can eliminate production hedging. We ask two specific questions: (1) If the firm can engage in financial hedging and eliminate any losses that stem from exchange rate fluctuations, can it manufacture the total demand and satisfy the global demand? (2) Can financial hedging increase the firm's expected profit?

Park et al. (2014a) shed light on these two questions with a comprehensive analysis. Firms may use various forms of financial instruments in hedging: a forward contract, a futures contract, or a currency option. Regardless of the type of instrument, Park et al. (2014a) show that financial hedging (1) cannot increase the manufacturer's expected profit, and (2) cannot alter the optimal manufacturing quantity. Thus, we conclude that financial hedging cannot eliminate production hedging. As a result, 1 is still greater than 2, even in the presence of financial hedging.

Financial hedging can add value to a risk-averse manufacturer, but cannot eliminate production hedging; rather, it makes production more pronounced under risk aversion. Many financial institutions are bound to comply with the Basel II and III Accords established by the Basel Committee on Banking Supervision (2011). Basel II and III mandate that financial institutions must hold a sufficient amount of cash to cover risk exposure based on value-at-risk (VaR) (see Kou, Peng, & Heyde, 2013). In turn, financial institutions increasingly lend money or underwrite contracts with similar cash holding requirements for manufacturers in order to reduce their own risk exposure. How does risk aversion with VaR-based requirements change the optimal manufacturing decisions of the global firm? Park et al. (2014a) show that VaR-based requirements put additional pressure on firms to reduce the manufacturing quantity. Thus, production hedging can still be optimal for a risk-averse firm that is forced to comply with a VaR measure. Once again, 1 is still greater than 2.

5. Insights and conclusions

We conclude with five beneficial insights for practicing managers:

1. The global firm should incorporate exchange rate uncertainty into supply chain planning. As the popular saying in finance goes, "If there is risk, there is opportunity." When fluctuations in exchange rates are managed carefully, a global firm can convert its challenge into an opportunity to make higher gains.

2. Less is more under exchange rate uncertainty. Manufacturing a smaller quantity creates the flexibility of distribution allocation based on exchange rate fluctuations, and generates higher profits. Our production hedging design resembles the practice of popular Spanish apparel maker, Zara. Zara commits to a smaller quantity in order to reduce the risk of leftover inventories in its retail stores. Consequently, consumers know to buy any Zara apparel they might like because it may not be available the next day. Production hedging with the commitment to a smaller quantity can have additional practical value beyond the benefits reported under exchange rate uncertainty.

3. Production hedging becomes more desirable under volatile exchange rates and low profit margins.

Mature products with properties resembling commodities exhibit these characteristics, and therefore are viable candidates in practice.

4. It is not always bad to lose market share. Our work helps marketing executives quantify the economic value of market share. If the perceived value of market share is significantly higher than the economic value, these executives can continue to serve all of the firm's global demand; however, they now know the penalty cost of their strategic decision.

5. Financial hedging does not eliminate production hedging. While such insurance instruments are beneficial, they prove costly in practice. Our work shows how global firms can create financial value without engaging in financial hedging.

Appendix

Details of the mathematical model

Parameters:

i: index representing various markets, i = 1,. . .N
c: unit manufacturing cost (denominated in home-country currency)
t_i: unit transportation cost from manufacturing country to market i (denominated in home-country currency)
r_i: unit selling price (denominated in local currency of market i)
d_i: demand in market i
α: percentage of demand in each market required to be satisfied, $0 \leq \alpha < 1$
$\tilde{e}_i$: random exchange rate defined on a support $[0,\infty)$, with $\mathbf{e}$ as the vector representing realizations of exchange rates in markets i = 1,. . ., N and the joint probability density function $f(\mathbf{e})$

Decision variables:

X: amount of manufacturing quantity in the presence of exchange rate uncertainty in Stage 1
x_i: amount of products allocated from the manufacturing country for sale in market i in Stage 2

The model:

Stage 1: The firm determines the optimal amount of manufacturing quantity X that maximizes the expected profit $E[\Pi(X)]$ in the presence of exchange rate uncertainty.

$$\max_{X \geq 0} E[\Pi(X)] = -cX + \int \pi^*(X, \mathbf{e})\, f(\mathbf{e}) d\mathbf{e} \tag{1}$$

where $\pi^*(X, \mathbf{e})$ is the optimal second-stage profit for a given X and exchange rate realization $\mathbf{e}$.

Stage 2: After observing the realized values of exchange rates $\mathbf{e}$, the firm determines the amount of products to be allocated to each market x_i that maximizes the profit $\pi(x_1,. . ., x_N\,|X,\mathbf{e})$ without exceeding the amount manufactured in Stage 1 or demand in each market.

$$\pi^*(X, \mathbf{e}) = \max_{(x_1,\ldots,x_N) \geq 0} \pi(x_1, \ldots, x_N | X, \mathbf{e}) = \sum_{i=1}^{N} (r_i \mathbf{e}_i - t_i)^+ x_i$$

s.t.

$$\sum_{i=1}^{N} x_i \leq X \tag{2}$$

$$\alpha d_i \leq x_i \leq d_i \quad \forall i = 1, \ldots, N \tag{3}$$

Constraint (2) requires that the total amount of products distributed in Stage 2 cannot exceed the amount manufactured in Stage 1. Constraint set (3) enforces that the amount allocated to each market cannot exceed its local demand d_i; moreover, if the firm requires that a certain percentage of demand must be satisfied with $0 < \alpha < 1$, then constraint set (3) ensures that the allocation exceeds this percentage.

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