MS-E2177

Seminar on Case Studies in Operations Research

Optimal currency hedging in global pulp markets

Final report

Team:
Matias Linnankoski (Project manager)
Joni Karras
Elin Nyman
Zhongqing Yang

Client:
UPM

June 1, 2020

Contents

1 Introduction **2**

1.1 Background . . . 2

1.2 Motivation . . . 3

1.3 Objectives . . . 4

2 Literature review **6**

2.1 Financial risk management and hedging . . . 6

2.1.1 Financial risk management . . . 6

2.1.2 Objectives of hedging . . . 6

2.2 Hedging practices and instruments . . . 8

2.3 Currency exposure and hedging . . . 10

2.3.1 Types of currency exposure . . . 10

2.3.2 Hedge ratio . . . 11

3 Data and methods **13**

3.1 Data analysis . . . 14

3.2 Validation . . . 17

4 Results **19**

4.1 Softwood . . . 19

4.1.1 Europe . . . 20

4.1.2 China . . . 23

4.2 Hardwood . . . 25

4.2.1 Europe . . . 26

4.2.2 China . . . 28

5 Discussion **29**

6 Conclusions **31**

References **32**

7 Self assessment **35**

7.1 Project progression . . . 35

7.2 Success of the project . . . 36

7.3 Improvement areas . . . 36

1 Introduction

1.1 Background

All companies confront risks: liquidity risk, price risk, non-payment risk, investment risk, currency risk, and interest rate risk [1]. Investment projects cannot be executed without a risk analysis, as the negative effects should be minimized beforehand to avoid solvency and liquidity [2]. For most economic actors, currency risk management due to exchange rate fluctuations attracts much attention, as international transactions are unavoidable between partners in different countries or currency areas. Moreover, global corporations are exposed to currency risk that arises in the course of purchasing raw materials and selling their products in multiple countries [3].

For the pulp market, the growth of timber consumption and demand from China has been extremely important for countries such as Finland, Sweden, and Russia [4]. The pulp market is a global commodity market with some special characteristics, including widespread contracts, monthly pricing, quality differences and supplier preferences, and appreciation for reliability. For widespread contracts, market pulp producers and consumers make annual contracts on volume and commercial terms, with some space for spot volume for flexibility. In addition, price negotiations for contract volumes take place monthly. Some contracts rely on third-party indexes. Customers can even have preference beyond types, up to mills of preference. Based on the current pulp market, the currency management is conducted for the specific company in this study.

According to economic papers related to hedging and invoicing strategies, exchange rate forwards are the most commonly used derivative tool [5]. Euro area non-financial blue-chip companies systematically use financial derivatives to hedge transaction risk. In this case, hedge ratios seem to be close to 100 percent for firmly committed cashflows and lower for estimated or expected flows. Short maturities up to two years are most widespread for exchange rate forwards and options, while it is not unusual to see cross-currency swaps with maturities of a decade or more. However, by exploring several firms, the management of translation risk is not completely documented and appears to differ significantly across firms. Some firms rely on rolling over short-term derivative hedges. Many reduce their exposure to economic risk by matching of costs and revenues, either through financial instruments or through the geographical structure of sourcing, production, and sales.

1.2 Motivation

It is commonly agreed that a firm faces exchange rate exposure if its value is influenced by changes in exchange rates [6]. The minimization of the impact of foreign exchange rate fluctuations is the main hedging motive on the variability of the firm's operating cashflow. Meanwhile, hedging can also reduce the probability of financial distress and bankruptcy. Corporations seek to protect themselves and reduce the risk effectively. However, Rawls et al. [5] note that hedging may not benefit all firms, which is the reason why hedging strategies vary between different firms, but hedging is a primary objective to financial managers. Exchange rate variability will cause the profits, and the value of an exposed firm, to either generate a higher or a lower value of the firm. Economic exposure is concerned with the sensitivity of the cashflow to the exchange rate.

The Modigliani-Miller theorem states that it is impossible for a firm to add extra value through hedging in a perfect world without taxes and transaction costs [7]. However, the real world with transaction costs, taxes, and sometimes limited information makes risk management practicable in firms, to be less affected by the exchange rate. Moreover, according to financial theory, the value of the firm is equal to the net present value of all expected future cashflows, which emphasizes the uncertainty faced by the company. If the reporting currency value of cashflows changes due to exchange rate fluctuations, a firm that hedges its currency exposure reduces some of the variances in the value of its future expected cashflows. Hence, currency risk can be defined as the variance of the expected cashflows, which arise from unexpected exchange rate changes. Allayannis et al. [8] directly examine the relationship between foreign currency hedging and firm value measured by Tobin's Q ratio, based on a sample of 720 American non-financial firms with total assets of more than 500 million USD. By adding some control variables such as profitability and leverage into the regression model, they found that hedging is definitely related to firm value and that firms with hedging have, on average, 4.87 percent higher firm value than those without hedging. Mello and Parsons et al. [9] noted that a firm with no financial constraints cannot increase the firm value by hedging, but the higher constraints can contribute to the greater potential value from hedging. They also argued that the value of the hedge depends on the design or plan of the hedging strategy.

The results from their research showed that an increment in the commodity price can increase the value of the firm, however, a modest portion of this gain in value can be seen as an immediate cashflow. Conversely, a potential loss on the hedge must be paid in cash instantly[9]. Therefore, the financial risk created by the hedge itself is an important factor in determining the optimality of the hedge and how it can contribute to add value. Hedging would create its own liquidity if a hedge successfully locks in the firm's value, then by the definition short-term losses on the hedge can be precisely matched by an increase in expected future cashflows and the short-term losses should be easily financed. Otherwise, a weakly conceived hedge can improve the expected costs of financing, tighten the financial constraints, and reduce the value of the firm, which is a large issue to be considered when applied to the hedging strategy.

Chen et al. [10] examined short-run commodity/currency relationships in four commodity-exporting countries (Australia, Canada, New Zealand, and South Africa) using restriction-based causality tests and rolling out-of-sample forecasting analysis. They found that the currency returns of commodity-exporting countries are contemporaneously correlated with both broad and country-specific commodity return indices, which noted that commodity prices and currency exchange rates are closely related.

In finance, the EUR/USD currency pair is considered the most liquid currency pair in the world. The USD/JPY is regarded as the second most popular currency pair [11]. The trading of currency pairs is conducted in the foreign exchange market, also known as the forex market, which is the largest and most liquid market. This market allows for the buying, selling, exchanging, and speculation of currencies. It also enables the conversion of currencies for international trade and investment.

1.3 Objectives

In this report, we present the results of a case study on currency hedging in the global commodity market of pulp. Our client is UPM, a forest industry company that produces, among other things: pulp, label materials, communication- and specialty papers and wood products. UPM Pulp is part of the UPM Biorefining Business Area. Pulp is a clean, wood-based, renewable, and biodegradable raw material [12]. It can be used to produce paper, tissue, board, and specialty paper. UPM produces both hardwood and softwood pulp products. Hardwood pulp is made from eucalyptus or Nordic birch, while softwood is made from pine and spruce [13]. Hardwood and softwood pulp prices are not necessarily dependent on the same factors, and therefore it is maybe not the best solution to hedge them in the same way. For this reason, we will study them independently to see if the optimal hedging strategy differs for different pulp types.

UPM reports its profits in EUR. Most of UPM's production facilities are located in Finland, except for one pulp mill which is in Uruguay. However, the pulp price is determined in USD, which introduces a currency risk. To make matters a bit more complicated, the pulp price is correlated with exchange rates, mainly the EUR/USD rate.

In this work, we aim to find a strategy for hedging the currency exposure of revenue from the client's pulp sales. Our objective is to study different linear hedging methods based on forward contracts and compare their performance. Pulp prices are dependent on exchange rates, particularly the USD/EUR rate. We study the correlations of historical pulp prices with exchange rates to find out more about their dependencies and how we can take advantage of them in the hedging strategy.

This report is structured as follows. A literature review on the important theoretical concepts is in Section 2. Section 3 presents the data and methods used for implementing different hedging policies. The results from testing the strategies on historical data are found in Section 4. Section 5 includes an assessment of the results and the final conclusions are in Section 6.

2 Literature review

This section provides a literature overview of the main concepts of this study. Section 2.1 gives an introduction to financial risk management and hedging, and discusses objectives of hedging. Section 2.2 describes different hedging practices and instruments. Finally, Section 2.3 introduces currency exposures and how they can be hedged.

2.1 Financial risk management and hedging

2.1.1 Financial risk management

Financial investments are often risky due to various future uncertainties that cannot be accurately anticipated. Financial risk is only one type of risk out of many different risks companies can face. Financial risks can be divided into three different areas: credit risk, market risk and operational risk. Market risk is defined as the risk of losses in positions caused by movements in market prices. Different types of market risks are equity risk, interest rate risk and currency risk. In this report we will focus on currency risk management. [14]

Two main countermeasures to deal with financial risk have been developed: hedging and diversifying. The first approach, hedging, is implemented by buying derivatives, such as forwards or options, to protect against anticipated risks. The concept of hedging will be explained in more detail later. The other financial risk management approach is diversifying, which means that the investor diversifies their investments to reduce market risk. Risk diversification is useful when making investments decisions or when optimizing a portfolio, but for managing foreign exchange risk from pulp sales, hedging is the better alternative. [14]

To be successful, companies must usually take some risks. Therefore, the purpose of financial risk management is not necessarily to eliminate risks completely. Instead, the strategy is to keep the financial risk under control, which differs from risk management in other fields [14]. In general, an investment with a higher level of risk have a higher level of expected return [15].

2.1.2 Objectives of hedging

Hedging can be defined as the attempt to reduce the financial risks in normal business operations or risk arising from investments [16].

Hedging is a very important use of financial markets, and presently a crucial part of industrial activity. To manage their financial risks through hedging, the firm takes a position, either an asset, a contract or a derivative, such that the value of the position will change in the opposite way of the exposure [17]. Thus, hedging provides protection from loss, but it can also eliminate gain if the value of the hedged asset increases. Hedging currency risk, and hedging in general, have become more important as business environments have become increasingly international. Multinational companies usually hedge at least their foreign exchange risk.

Hedging can give non-financial companies to possibility to focus on their main activities. The expertise of such companies is not to predict exchange rates or commodity prices, and therefore it makes sense for them to hedge the risks associated with these factors. Hedging can help them cope with unexpected events like sharp movements in exchange rate. However, there are also reasons why some risks are left unhedged, which will be described next. [18]

According to Modigliani and Miller, hedging is irrelevant for a risk neutral company in a perfect market, since shareholders can hedge through diversification on their own at the same costs [8]. The classical theory also states that hedging does not increase the value of the firm [8]. However, in practice this is not the case because the Modigliani and Miller theorem does not take into account transaction costs, which makes hedging less expensive for the company than for shareholders [18]. In addition, the company's management usually has more information about the risks the company faces than shareholders. Imperfect markets also create other reasons to hedge their financial risks, hedging can e.g. help reduce taxes, financial distress and bankruptcy costs [19].

Another argument against hedging is that it can sometimes lead to a worse outcome. Hedging with options do not have this problem, but a hedge with forwards or futures can result in either an increase or a decrease in profit compared to with no hedge [18]. For example, if the exchange rate moves in the favourable direction, a forward position will lead to an offsetting loss and the company will be in a worse position than without hedging. Still, some studies (see [20]) show that forwards dominate options when hedging downside risk.

2.2 Hedging practices and instruments

The first step in the hedging process is to identify the risk exposure, which may not be an easy task [21]. Companies are exposed to many risks, both company-specific ones and market risks that are common to all similar firms [22]. When analysing which risks should be hedged, the company also must take into account if the risks are dependent on exchange rates, interest rates, commodity prices or firm operations. After deciding on which risks to hedge, the company needs to determine which hedging instruments to use for the hedging. Numerous different risk management tools and instruments are available on the market. The company can buy or sell financial derivatives, carry large cash balances, change its financial policy or hold foreign debt [22].

Derivatives are financial securities whose values are derived from the value of some underlying assets [16]. This asset can for example be a foreign currency. Examples of derivatives are forward contracts, futures, and options. Derivatives can be used to transfer risk related to asset price fluctuations and enable companies to reduce risk. In addition to hedging, derivatives can also be used for trading and speculative purposes [18].

A *forward contract* is a contract to buy or sell a specific amount of an asset at a specific price and at a specific time in the future [16]. The contract is made between two parties. The buyer, the party agreeing to purchase in the future, is said to have a long position, and the seller is said to have a short position. By using a forward contact on currency, the buyer and seller can lock in the currency exchange rate associated with a future currency transaction. Forward contracts are traded over-the-counter (OTC), which means that they are negotiated between the two involved parties and can be tailor-made according to specific requirements. For this reason, forward traders face the risk that the counterparty does not fulfill their part, e.g. due to default. In general, neither party pays any money to obtain the contract, all claims are settled at the defined future date [16]. The *forward exchange rate* (forward rate) is the agreed exchange rate that applies at delivery. Conversely, spot rate is the current exchange rate that would be used for immediate delivery of the currency [16].

A *future contract* is very similar to a forward contract. The difference between the two is that futures are standardized contracts that are traded on an organized exchange [16]. An exchange defines universal prices and provides security when individuals do not have make contracts directly with the counterparty and face the risk of counterparty default. Since futures are standardized, they can be less flexible than forward contracts, but this might also mean that the associated costs are smaller.

An *option* is the right, instead of the obligation, to buy or sell an asset at specified price at a specified time [16]. An option that gives the right to buy is called a call option, while an option that gives the right to sell is called a put option. The option itself usually has a price, usually referred to as the option premium. Options can be used to hedge exchange rate risk. As opposed to forwards, options allow you to make profit if the exchange rate move in the favourable direction, since there is no obligation to exercise them.

Exchange-traded markets, or derivatives exchanges, are places where people trade standardized contracts defined by the exchange [18]. The advantage of trading on an exchange is that traders do not have to worry about the creditworthiness of their counterparty [18].

Derivative trades can also take place in the *OTC (over-the-counter) market* [18]. In this case, the contract is made between the two parties directly. Banks, large financial institutions and fund managers are the main operators in OTC derivative markets [18]. Banks often offer commonly traded derivatives, for instance currency forwards, and they can always give a price for which they are ready to make the contract.

The choice of which derivative to use depends a lot on what type and level of risk the company is exposed to, and the costs of different derivative strategies [23]. The different types of foreign exchange exposures are described in Section 2.3. In addition to exposure type, the choice depends on whether the company wish to hedge long-term debt or short-term operating cashflows. Costs are the other important factor in the decision to use currency derivatives. Costs can be split up into costs of maintaining a risk management program in general, and costs associated with a particular derivative instrument [23]. The latter includes liquidity costs, transactions costs, costs of customization and costs originating from basis risk and counterparty default risk.

Forward contracts are relatively low-cost instruments suitable for hedging frequent and uncertain transactions. However, the use of forwards has a basis risk, which is caused by differences between the hedged transaction and the forward contract, such as different maturity or payoff date [23]. Basis risk is small for short-term cashflows and can be managed by hedging dynamically [23].

When a company owns an asset and expects to sell it in the future, they can hedge using a short hedge. A short position in forward contracts can be called a short hedge. A long hedge, which involves taking a long position, is suitable when a firm have to purchase an asset in the future and want to lock in the price today. [18]

2.3 Currency exposure and hedging

2.3.1 Types of currency exposure

Foreign exchange risk is the uncertainty that arises due to fluctuations in exchange rates. It has considerable effects on companies that trade in foreign currencies. Foreign exchange exposure is a measure of the possibility that a firm's profitability, net cashflow and/or market value will change because of exchange rate variations [17]. Exchange rate exposure can be divided into three different types: transaction, translation and operating exposure [17]. Economic exposure is a term sometimes used for the combined effect of transaction exposure and operating exposure [24].

Transaction exposure refers to possible changes in the value of future incomes or costs as a result of unexpected changes in exchange rates between the date when a firm commits to a transaction and the actual transaction date [24]. Transaction exposure can be hedged using derivatives which can increase firm value by reducing the variance of cashflows, thereby decreasing the likelihood of financial distress [25].

Translation exposure arises when a company has assets or liabilities that are valued in a foreign currency, which need to be valued in the local currency in accounting [24]. The underlying value of the asset is then exposed to currency fluctuations [24]. Multinational companies are often subject to translation exposure. Generally, it is recommended not to hedge against this kind of exposure, for two reasons [25]. First, the translation gains or losses are not always realized, and second, the gains or losses can be poor estimators of real changes in firm value [25]. For this reason, companies often focus on transaction hedging.

Another measure of exchange rate exposure is economic exposure. It measures to which degree movements in exchange rate affect the value of the firm [24]. Firm value is here defined as the present value of expected future cashflows. Economic exposure includes both transaction exposure of existing contracts, and operating exposure which is the value change of future revenue and costs [24]. In practice, economic exposure depends on a lot of different factors and is hard to identify and hedge.

Both transaction and operating exposure consider future cashflows. They differ in terms of which cashflows they deal with and why these depend on exchange rate [17]. Transactions, i.e. current and immediate contracts, are affected by short term exchange rate changes. But over the long term, changes in exchange rate can affect how prices change and how competitors react to this, which will in turn affect future business contractions that are not yet contracted for [17]. In this work, we focus on hedging the transaction exposure of the sales in USD.

2.3.2 Hedge ratio

So far, we have only considered full hedges, i.e. that 100 % of the future cashflow is hedged. The objective of currency hedging is to minimize the changes in value of a cashflow due to changes in exchange rates. This is achieved by combining the exposed asset with a hedge asset, thus creating a two-asset portfolio in which the assets will move in the opposite directions if the exchange rate changes. Most often, the hedging is constructed such that the total change in the two-asset portfolio value is zero if a perfect hedge asset exists. For example, a forward hedge forms a two-asset portfolio of the spot exposure and forward cover. When taking a full forward cover, no exposure remains. The variance in the portfolio value is zero. [17]

Sometimes, hedging 100 % of the exposure is not the best solution. In this case, the hedger may choose to only hedge a proportion β of the exposure. The *hedge ratio* is defined as

$$\beta = \frac{\text{Value of currency hedge}}{\text{Value of currency exposure}} \tag{1}$$

When hedging less that 100 % of the exposure, the value of the two-asset portfolio will change with the spot exchange rate [17].

If the currency is correlated with the asset to be hedged, hedging away all of the currency exposure is usually sub-optimal [26]. If the correlation and standard deviations of the currency exposure and the currency hedge are known, the optimal ratio to be hedged can be calculated with the minimum variance hedge formula [16]. The minimum variance hedge is a common method for hedging when there is basis risk, e.g. when there exists no futures contract identical to the currency exposure. Specifically, the hedge ratio β is calculated as [16]

$$\beta = \rho_{eh} \frac{\sigma_e}{\sigma_h}, \tag{2}$$

where σ_e is the standard deviation of the currency exposure, σ_h is the standard deviation of the hedge and ρ_{eh} is the correlation coefficient between the exposure and the hedge. The minimum variance hedge can be improved further by maximizing a utility function instead of minimizing variance [16]. In this way, the risk preferences of the investor can also be captured. If the utility function is chosen as a quadratic function, the result is the mean variance hedge [16]. However, the mean variance hedge is difficult to use in practice.

This type of hedging strategy, where a constant fraction of the currency exposure is hedged, is called a linear hedging strategy, since the portfolio returns are a linear functions of the returns of the hedged currencies [26]. Studies show that for linear hedging strategies, the optimal amount to hedge is specific to each currency [26, 27]. Linear hedging strategies remove currency gains as well as losses. An investor who wants to remove losses from currency risk while keeping the possibility for currency gains, then can use non-linear hedging strategies [17]. Non-linear hedging strategies are implemented using options and in exchange for the potential gains, investors must pay the cost of the option premium. In our work, we focus on linear hedging strategies using forwards. We will hedge with hedge ratios smaller than 100 % to reduce the risk for large losses.

3 Data and methods

The currency data included spot prices, future prices, interest rates and implied volatilities. The spot prices were used for finding dependencies between the pulp prices and currency rates. For the pulp prices, we received data for both pulp types, bleached hardwood kraft pulp (BHKP) and northern softwood kraft pulp (NBSK). In addition, there are different price indices for Europe (PIX) and China (RISI). Consequently, we use four different price indices for pulp in our studies.

Both first-step analysis and literature studies suggested that the pulp prices are dependent on multiple currency pairs, rather than of a single one. Therefore, we constructed indicators which were weighted sums of currency pairs. The arithmetic currency indicators C were constructed as follows

$$C_t = \sum_{j=0}^{n} \alpha_j \cdot S_{j,t} \ , \tag{3}$$

where $S_{j,t}$ is the exchange rate for the currency pair j at time t, α_j the weight for the currency pair j and n is the amount of currency pairs used. The weight α contains information about both the magnitude of the exchange rate and its importance. We measure the importance of the currency with the weight w, so that the weight α can be expressed as

$$\alpha_j = \frac{w_j}{S_{j,0}} \ . \tag{4}$$

The dependencies between currencies and pulp prices were measured by returns. The returns describe how much the prices and currencies change with respect to each other during a selected return period. The returns are defined as

$$R_t = \frac{S_t}{S_{t-j}} \ , \tag{5}$$

where S_t is a price of the, exchange rate or a currency indicator at time t, and j the time horizon of the returns. In other words, R_t describes the proportion of how much the price has changed during $[t-j, t]$.

In addition, we used moving averages for the currencies in order to smooth them. The pulp price is not affected by rapid movements in the currencies and basing the performance of the hedge on a single exchange rate spot price is inadequate. The moving average of a price S is calculated as

$$S_{ma,t} = \frac{t}{t-j} \sum_{k=t-j}^{i} S_k \ ,$$

where j is the window of the moving average. Moving averages can be used when hedging, by taking smaller positions in forwards that have maturities within a window before receiving the cashflow.

As the derivatives used were limited to forwards, we only need the payoff formula for a forward contract. The payoff of an forward is defined as

$$P = N(X - S_t) ,$$

where N is the amount of positions, which can take both negative and positive values, X the delivery price, and S_t the spot price at maturity.

3.1 Data analysis

The analysis part was divided into two parts: i) correlation analysis, and ii) hedging simulation. The first part included a review on how foreign currency pairs (abbreviated as fx pair from now) move in time and how different fx pairs correlate with pulp price indices. Price levels as described, are measured on a monthly level. Since the currency market is considered as a perfect market at least in short term, the possible biased ratings in price levels exist only for short periods of time. Partly because of this, hedging and therefore correlation analysis in performed on a monthly level with ignoring fluctuation in narrower time frame. Assigning normal price levels free from exogenous shocks in the global market in general and in the pulp market, or from business cycle was considered hard with records only on monthly level.

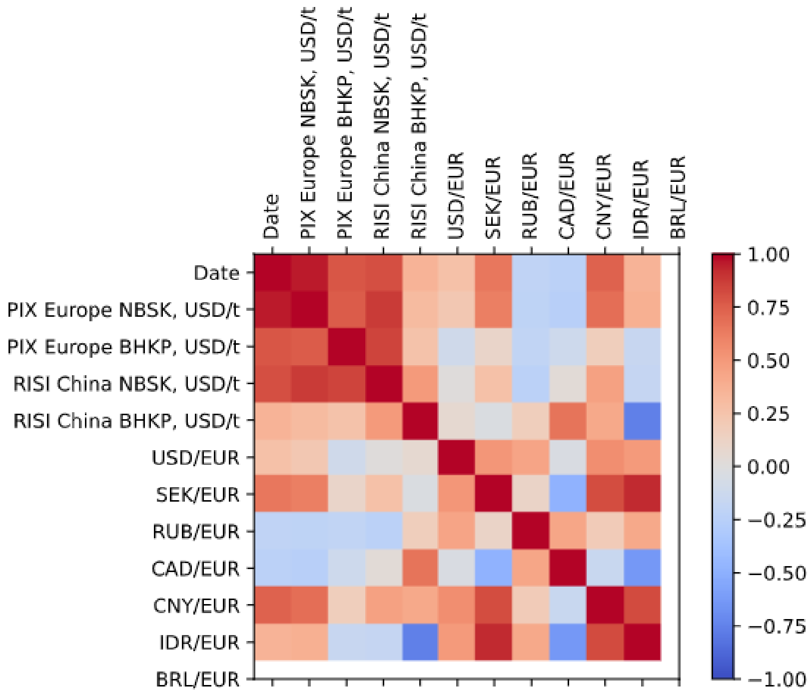

Figure 1: Correlation matrix between FX pairs and pulp indices. Time period 05/2000 - 12/2019.

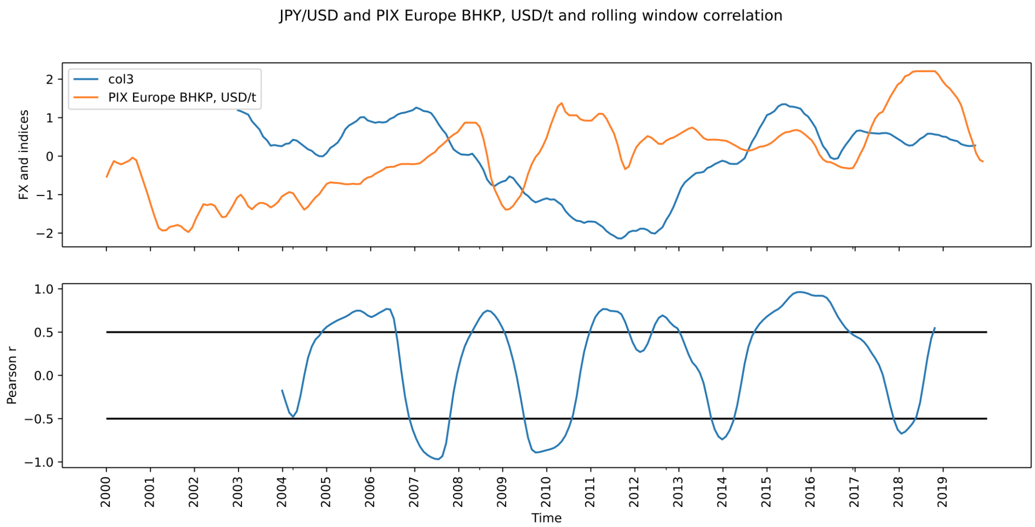

Figure 2: JPY/USD and PIX EUR BHKP correlation through time. JPY/USD is calculated with a 24 months moving average window.

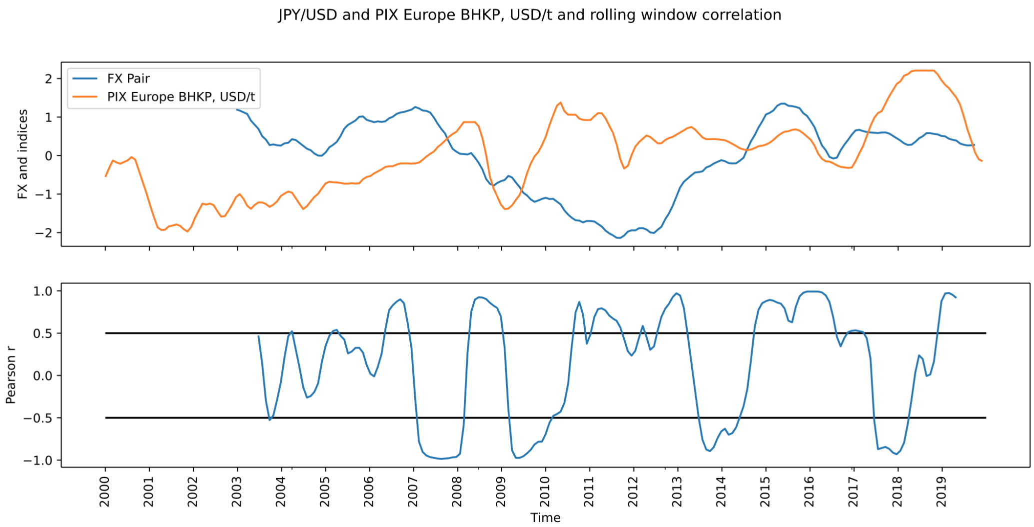

Figure 3: JPY/USD and PIX EUR BHKP correlation through time. JPY/USD is calculated by 12 months moving average window.

Valid time periods for hedging without a need of taking exogenous shocks into an account, was divided into three sections:

i years 2000-2008, time before global financial crisis

ii years 2008-2012 time before drop in pulp price

iii years 2012-2020.

The correlation analysis produced potential results when the data set was split into these time periods. In each period, price level volatility was considered homogeneous as well as the overall trend. When measuring cross-correlation for bigger time frames, the correlation levels seemed to make big shifts from strong positive correlation to strong negative correlation, without any significant seasonality or trend fluctuation. In addition, changes in cross-correlation levels seem to be very rapid and strong even on a quarterly basis. To record more stable changes in the correlation level across time, a moving average was calculated separately for the fx pairs and for the pulp price indices. A moving average window wider than 12 months seemed to give the most stable correlation plots as shown in Figures 2 and 3. Even with the stabilizing approach, the correlation levels tend to shift rather much to be convenient for stable hedging.

Other approach for mitigating changes in correlation levels were to iteratively search for optimal amount of lag between pulp prices and fx pairs. EUR index seemed to give a good ground truth on how correlations level between pulp and fx pair vary between different lags. This is demonstrated in Figure 4. In the figure, the Pearson's correlation is calculated for every pulp price index against the shifted time series by each lag value. In general, currency pair and pulp prices seem to correlate best when currency time series is shifted by 6 to 12 months backwards, except for RISI China BHKP, which has a different curvature compared to other indices.

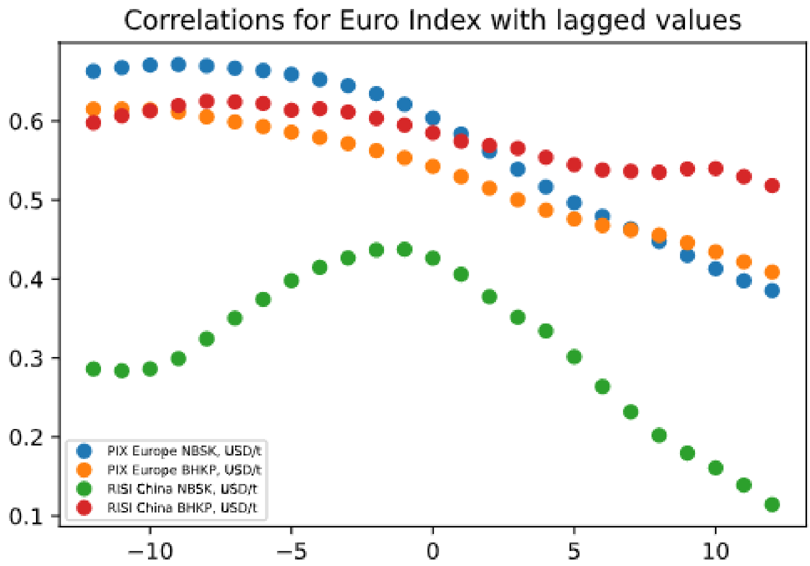

Figure 4: Scatter plot of correlations between EUR index and different pulp market indices. X-axis represent lag levels in months, from -12 months to +12 months. Time period 05/2000 - 12/2019.

3.2 Validation

The results of the data analysis were validated by testing the hedging strategy on the historical data. As with the data analysis, the hedging was carried out separately for all four pulp prices indices. To enable the testing of different strategies, the inputs were inserted manually to the hedging tool and not directly from the data analysis results.

In the simulations, we assume to receive one cashflow per month, equal to the price index at that moment. In other words, we assume that we sell 1 ton of pulp each month, such that the cashflow to be hedged correspond to the pulp price per ton. Based on the data analysis, we set weights for the different currency pairs, which we use when hedging. The weights describe how much the pulp price changes with regard to changes in the exchange rate for the currency pair. On request from the client, the maximum amount of currencies included in one strategy was limited to four.

Each of the bought forward contracts are assigned to some certain future payment, such that the expiry date does not need to match the date of the cashflow. After the simulation, the changes in the portfolio were summed with the changes in the pulp price. In an ideal situation, these changes would cancel each other out, but in this case it is unreachable. The following paragraph presents the validation method in a more mathematical form.

Assume that we will receive a cashflow at time T with a value corresponding to the pulp price at that moment. During the time period $[0,T]$ the value of the received cashflow will change by

$$\Delta CF_T = CF_T - PP_0 \ .$$

The goal is to cancel out the change in the cashflow, ΔCF_T, caused by currency fluctuations. In order to do this, we will construct a portfolio $\Pi_T = (F_1, F_2, ..., F_n)$ containing n forwards, possibly with different currencies and maturities. The payoff of this portfolio will be

$$P(\Pi_T) = \sum_{i=0}^{n} N_i (X_i - S_{i,T_i}) \ ,$$

where N_i is the position quantity, X_i is the delivery price of the forward, T_i is the maturity and S_{i,T_i} is the spot price of the underlying at the maturity of the forward F_i.

The performance of a hedge for a single cashflow is evaluated as

$$\Delta CF_{T,\text{hedged}} = \Delta CF_T + P(\Pi_T) \ .$$

The simulation hedges the monthly cashflows during a chosen time period in a similar manner. The only thing which changes is the amount of positions, which is proportional to the pulp spot price at the execution of the hedge.

The total performance is evaluated by calculating the mean and variance of the performance of the single hedges executed during the simulation. These will be compared to the mean and variance of the unhedged changes. The time interval for the validation was chosen as 2013-2019.

4 Results

The results for each pulp type were obtained iteratively. The final variables considered for the hedging were:

- Used currencies
- Weights for currencies
- Time horizon
- Moving average window

The currencies are determined by examining which currencies affect the pulp prices the most. This is the most critical step of the study. The time horizon section describes the time interval of the hedging. This is determined by examining the correlations between the returns for different time periods.

The pulp price data ranges from the early 2000 to 2019. The first step was to divide the data into three different periods, before the 2008 financial crisis, the 2008 financial crisis and after the 2008 financial crisis. During and after the financial crisis in 2008, the currencies and pulp prices behaved unexpectedly and were very volatile. Including this data would lead to misleading results. We aim to hedge the transaction risk from the cashflows. The fluctuations in exchange rates affect the profits of pulp producers, and the purchasing power of customers. These imbalances are corrected with a change in the pulp price. To address this problem, we want to solve how the exchange rates affect the pulp price in US dollars. The translation risk can then be hedged by buying forwards between the domestic currency and USD, with a notional corresponding to the estimate of the hedged future cashflow in USD. UPM has multiple of subsidiaries which measure their profits in different currencies, so therefore the domestic currency is not denoted as EUR.

For implementation of the hedging strategy, moving average method was used which in this case indicates that for the period of time (window width in moving average) the cashflows are bought in equal shares of total hedge before executing the forwards.

4.1 Softwood

Based on the clients proposal, our hypothesis was that softwood prices depend on how EUR compares to different currencies. This assumption is based on the production locations of softwood, which is mainly in Europe. The results supported this hypothesis, and the best results were achieved with currency pairs containing EUR.

The correlation analyses of exchange rates and the two softwood price indices yielded similar results. The most significant correlations for the returns were found with the currency pairs EUR/JPY and EUR/USD. Thus, they were taken into consideration for the hedging simulation.

4.1.1 Europe

Table 1: Performance for 12 month hedges with combinations of USD/EUR and JPY/EUR.

Weights		MA window	Mean	SD
EUR/USD	EUR/JPY		$\Delta CF_{\text{hedged}}$	$\Delta CF_{\text{hedged}}$
1	0	1	101.4	115.5
0	1	1	88.9	117.3
0.5	0.5	1	88.4	113.0
0.75	0.25	1	92.8	113.4
0.25	0.75	1	87.2	114.4
1	0	3	100.0	114.7
0	1	3	88.5	116.7
0.5	0.5	3	87.8	112.8
0.75	0.25	3	92.2	113.0
0.25	0.75	3	86.9	114.0
		ΔCF without hedge:	111.9	132.9

Figure 5 contains two subplots describing the hedge performance of the strategy proposed in the first row of Table 6. The first subplot illustrates the changes in the portfolio and cashflows during the 12 month time periods. In an ideal situation the lines would sum up to 0. The second subplot illustrates the value of the hedged and unhedged cashflows. Note that during the first 12 months they are equal since the hedging is started at time 0.

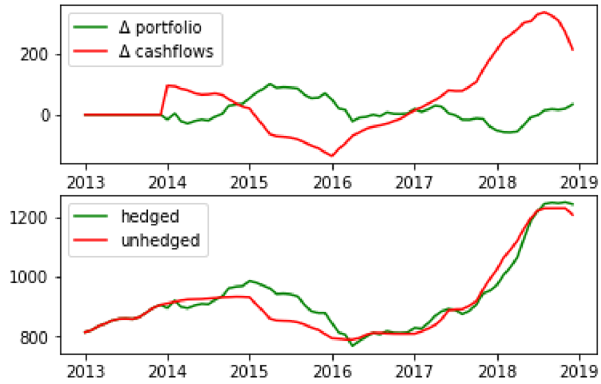

Figure 5: Performance of a 12 month time horizon hedge when the hedging instrument is EUR/USD.

As seen, the changes in the portfolio cancels the changes in the pulp price moderately. The mean absolute changes for the hedged were roughly 26% smaller than for the unhedged ones. The EUR/USD hedge was tested for longer timehorizon with different moving averages. For a 18 month timeperiod, the mean absolute changes in the cashflows could be reduced with 17 %. The results of this are vizualized in table 2.

Table 2: Performance for 18 month hedges with USD/EUR with different moving average window.

MA window	Mean $\Delta CF_{\text{hedged}}$	SD $\Delta CF_{\text{hedged}}$
1	122.8	141.1
2	122.4	140.5
4	121.5	139.8
6	120.2	139.6
8	118.7	140.0
ΔCF without hedge:	142.3	171.0

The effect of the moving average window is seen by comparing Figures 6 and 7. We see how the performance of the portfolio is less volatile when buying multiple forwards with different maturities per cash flow.

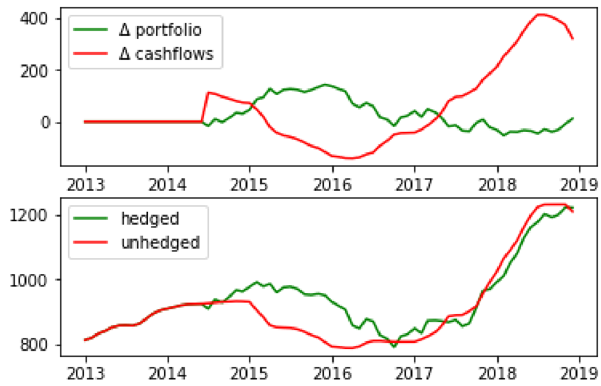

Figure 6: Performance of a 18 month time horizon hedge when the hedging instrument is EUR/USD and moving average window 1.

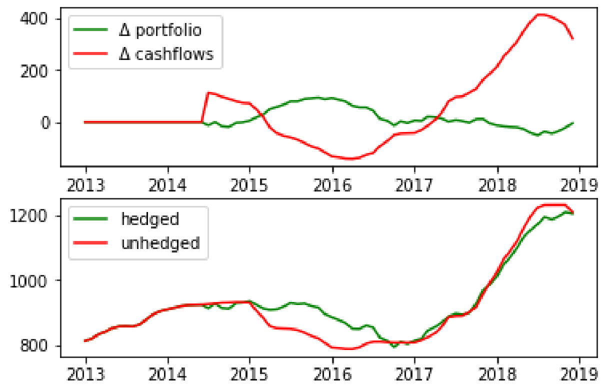

Figure 7: Performance of a 18 month time horizon hedge when the hedging instrument is EUR/USD and moving average window 8.

4.1.2 China

Table 3: Performance for 12 month hedges with combinations of USD/EUR and JPY/EUR

Weights		MA window	Mean	SD
EUR/USD	EUR/JPY		$\Delta CF_{\text{hedged}}$	$\Delta CF_{\text{hedged}}$
1	0	1	80.7	103.0
0	1	1	79.2	102.4
0.5	0.5	1	75.3	100.4
0.75	0.25	1	77.3	101.1
0.25	0.75	1	75.9	100.8
1	0	3	81.4	103.7
0	1	3	79.7	103.1
0.5	0.5	3	77.2	101.4
0.75	0.25	3	78.6	102.0
0.25	0.75	3	77.3	101.7
		ΔCF without hedge:	96.5	121.9

The results were similar as with the Europe price. Although EUR/JPY performed outperformed EUR/USD by the numbers, the EUR/USD showed significantly better results when validated visually. By hedging with USD/EUR the mean change of the cashflows were reduced with 18%. Hedging performances with EUR/USD, EUR/JPY and EUR/USD combined with EUR/JPY are vizualised in Figures 8, 9 and 10, respectively.

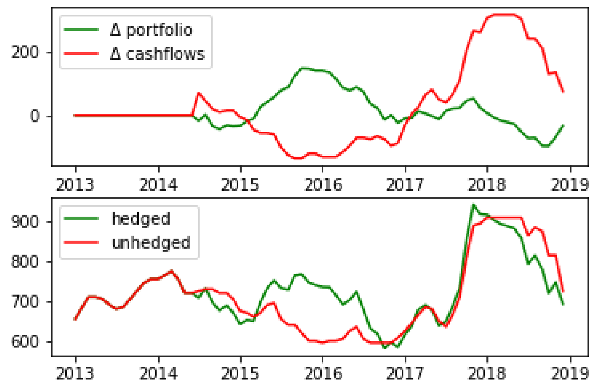

Figure 8: Performance of a 12 month time horizon hedge when the hedging instrument is EUR/USD.

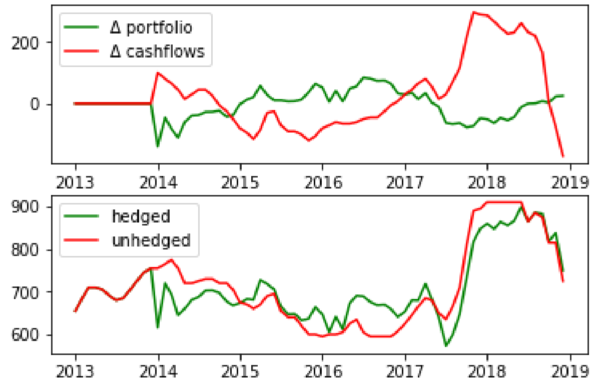

Figure 9: Performance of a 12 month time horizon hedge when the hedging instrument is EUR/JPY.

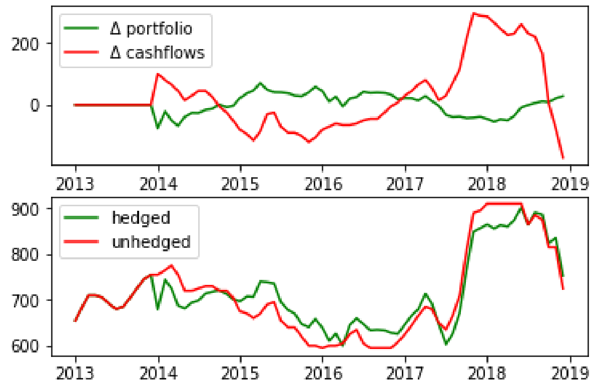

Figure 10: Performance of a 12 month time horizon hedge when the hedging instrument is EUR/USD and EUR/JPY.

Table 4 shows the hedge performance for a 18 month timehorizon with different moving averages. For a 18 month timeperiod, the mean changes in the cashflows could be reduced with 28 %.

Table 4: Performance for 18 month hedges with USD/EUR with different moving average windows.

MA window	Mean $\Delta CF_{\text{hedged}}$	SD $\Delta CF_{\text{hedged}}$
1	92.5	100.3
2	91.2	100.3
3	89.8	100.6
4	88.9	101.2
5	87.9	102.0
6	86.8	103.0
ΔCF without hedge:	118.1	145.1

4.2 Hardwood

While softwood is produced mostly in Europe, hardwood is mainly produced in South America. This brings us to the hypothesis that the price of hardwood pulp depends on how USD compares to other currencies. The results do not strictly support the hypothesis.

The results for both PIX Europe BHKP and RISI China BHKP are presented in Tables 5 and 6. The results were not as straightforward as for the softwood. The prices seemed to be more dependent of USD/JPY and USD/UYU than USD/EUR, which was unexpected.

4.2.1 Europe

Table 5: Performance for 12 month hedges with combinations of EUR/USD,USD/JPY and USD/UYU

Weights			MA window	Mean	SD
EUR/USD	USD/UYU	USD/JPY		$\Delta CF_{\text{hedged}}$	$\Delta CF_{\text{hedged}}$
1	0	0	1	119.2	134.1
0	1	0	1	114.8	137.3
0	0	1	1	109.6	136.0
0.5	0.5	0	1	116.3	135.2
0	0.5	0.5	1	111.4	135.2
0.33	0.33	0.33	1	113.0	134.2
0.67	0.33	0	1	117.2	134.7
0.33	0.67	0	1	115.6	135.8
1	0	0	3	112.9	144.7
0	1	0	3	113.8	136.5
0	0	1	3	108.8	135.1
0.5	0.5	0	3	112.7	140.0
0	0.5	0.5	3	110.5	134.6
0.33	0.33	0.33	3	111.2	137.8
0.67	0.33	0	3	112.6	141.4
0.33	0.67	0	3	112.9	138.6
			ΔCF without hedge:	112.6	132.3

None of the results yielded desirable results. Some of the combinations were able to beat the unhedged cashflows, but this is most probably due of overfitting. The 6 year time interval is relatively large and this implies that the EUR/USD would not be suitable for hedging this pulp price. Figure 11 illustrates the performance of the EUR/USD hedge.

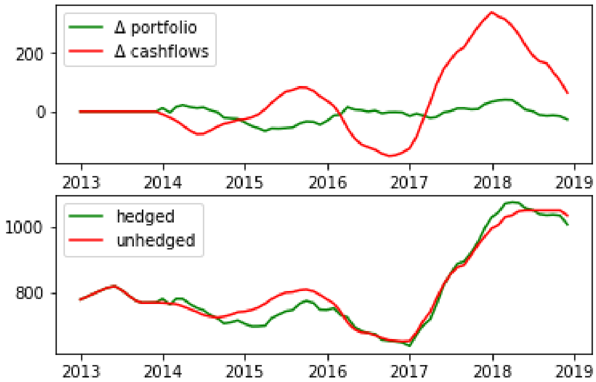

Figure 11: Performance of a 12 month time horizon hedge when the hedging instrument is EUR/USD.

4.2.2 China

Table 6: Performance for 12 month hedges with combinations of USD/EUR, JPY/EUR and USD/EUR.

Weights			MA window	Mean	SD
EUR/USD	USD/UYU	USD/JPY		$\Delta CF_{\text{hedged}}$	$\Delta CF_{\text{hedged}}$
1	0	0	1	91.3	100.5
0	1	0	1	89.2	109.7
0	0	1	1	83.8	90.1
0.5	0.5	0	1	87.0	98.9
0	0.5	0.5	1	82.6	91.5
0.33	0.33	0.33	1	85.3	92.9
0.67	0.33	0	1	88.0	98.0
0.33	0.67	0	1	86.6	101.3
1	0	0	3	91.0	100.0
0	1	0	3	85.2	103.4
0	0	1	3	83.7	90.2
0.5	0.5	0	3	85.8	96.2
0	0.5	0.5	3	81.4	89.3
0.33	0.33	0.33	3	84.4	91.5
0.67	0.33	0	3	87.2	96.3
0.33	0.67	0	3	85.0	97.5
			ΔCF without hedge:	97.8	105.0

As with the Europes hardwood price, USD/EUR showed insignificant results for hedging. However, USD/UYU and USD/JPY performed reasonably well. When hedging was performed with USD/UYU and USD/JPY the mean changes in the cashflows reduced with approximately 10-20%, depending on the weights.

Figure 12 and 13 visualises the hedging performance when the instruments are EUR/USD and USD/UYU combined with USD/JPY.

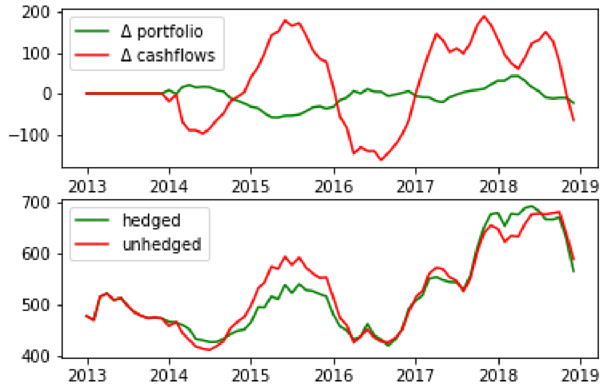

Figure 12: Performance of a 12 month time horizon hedge when the hedging instrument is EUR/USD. The used moving average is 3.

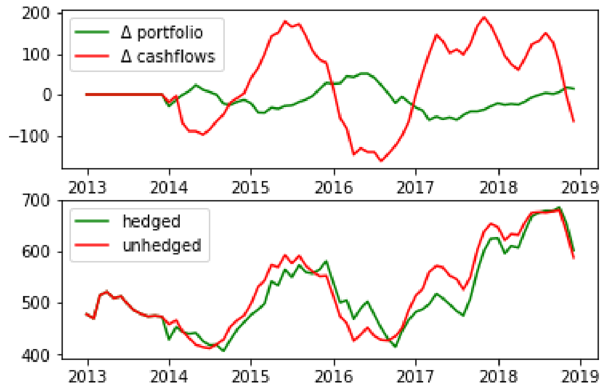

Figure 13: Performance of a 12 month time horizon hedge when the hedging instruments are USD/UYU and USD/JPY. The used moving average is 3.

5 Discussion

The results were calculated with daily spot and forward prices, although the maturities used differed in months. This makes the hedge performance dependent on single day spot prices, which causes unwanted deviation. This could be mitigated by buying multiple forwards for each month, with smaller positions.

The moving average approach seemed to give good results as in correlation study. By stabilizing the forex fluctuation in the hedging strategy, the overall performance seemed to increase. This also helps avoiding bad hedging performance when unpredictable shifts in forex fluctuation happens.

The moving average approach also addresses the lags on a general level, so no additional adjustments from the correlation analysis were implemented in selecting the optimal lag level between fx pairs and pulp prices.

After an iterative approach with varying combinations of hedged currencies, moving average window and magnitude of the hedge, the following key findings were observed. When selecting the optimal currencies to use in the hedging portfolio, Uruguayan peso was found to be most volatile and hence should not be used on its own.

For hardwood pulp, USD/EUR did not seem to perform well despite the initial assumption. Instead, USD/JPY seemed to perform surprisingly well in hedging simulations for hardwood. Basic reasoning here would state that Japanese yen reacts better to changes in pulp prices in Asian region. By general hypothesis shift in pulp prices in Asian markets will make similar level of shift in Western markets approximately 1 quarter later.

Of the pulp price indices, NBSK were found to be easier to hedge than BHKP. The worst results were obtained when hedging the PIX BHKP index with only some of the selected hedges gave better values on mean of changes in cashflow compared to variation without the hedging at all. With RISI China BHKP best hedges give mean for cash flow fluctuation values from 90 to 93 while the cashflow fluctuation without hedge is 114.7. Also standard devision of fluctuation decreases to level of 105 to 110 on best hedged while cashflow fluctuation without hedge is on a level of 138.8.

6 Conclusions

Modelling the dependency structure between the pulp prices and currency rates turned out to be more complex than expected. The study was started by examining the correlations between the returns of pulp prices and currencies. The correlations seemed to change significantly during different time intervals. The idea of a fully automated model was discarded, since the hedging requires continuous qualitative analysis for the data. The pulp prices are affected by multiple other factors than currency rates, and separating them from each other was not in the scope of this project.

The analysis implied that the optimal window for predictability dependency was in the range from 10 to 18 months. The moving averages were found to be effective, decreasing the volatility of the hedge profits.

Multiple different strategies were tested, each containing one to three exchange rates. For the softwood, the use of multiple currency pairs rates did increase the performance. The best results were obtained by using only USD/EUR. For the hardwood, USD/UYU and USD/JPY gave the best results. Uruguay is one of the worlds largest pulp producers, which explains the dependency between USD/UYU and hardwood pulp prices. In case qualitative reasoning is found for the dependency with USD/JPY, it could be considered for hedging. The team was not able to come up with a non speculative reasoning for this.

Some strategies which seemed to work fine during a more stable time period produced considerable losses when tested on the time period of the market crash. To decrease the vulnerability of the hedging towards black swans, we propose the use of the use of option spreads. This would create an upper and lower limit for the profit of the hedges.

For further development of the project, we suggest to model the shipment data of pulp. Combining these with the changes in purchasing power and profit margins of the pulp producers could yield more reasonable results. We were able to find basic hedges which performed considerably well, but in order to construct these, the data had to be carefully reviewed. More work will have to be done in order to develop a harmonized or semi-automated model. In our project we exploited the data visualizations to find different stable time periods where the parameters adjusted and then tested.

References

[1] J. F. Solomon and N. L. Joseph, "Which corporate hedging motives are appropriate? An institutional shareholders' perspective," *International Journal of Finance & Economics*, vol. 5, no. 4, pp. 339–347, 2000.

[2] S. Álvarez-Díez, E. Alfaro-Cid, and M. O. Fernández-Blanco, "Hedging foreign exchange rate risk: Multi-currency diversification," *European Journal of Management and Business Economics*, vol. 25, no. 1, pp. 2–7, 2016.

[3] C. K. Shahi, *Economic analysis of the north american softwood lumber markets*. PhD thesis, University of Toronto, 2008.

[4] T. Hein, "Tracking price movements in the pulp market," *Pulp and Paper Canada*, vol. 119, no. 1, pp. 16–17, 2018.

[5] B. Döhring, "Hedging and invoicing strategies to reduce exchange rate exposure - a euro-area perspective," European Economy - Economic Papers 2008 - 2015 299, Directorate General Economic and Financial Affairs (DG ECFIN), European Commission, 2008.

[6] F. Castellaneta, R. Conti, and A. Kacperczyk, "Money secrets: How does trade secret legal protection affect firm market value? evidence from the uniform trade secret act," *Strategic Management Journal*, vol. 38, no. 4, pp. 834–853, 2017.

[7] G. Allayannis and J. P. Weston, "The use of foreign currency derivatives and firm market value," *The Review of Financial Studies*, vol. 14, no. 1, pp. 243–276, 2001.

[8] F. Modigliani and M. H. Miller, "The cost of capital, corporation finance and the theory of investment," *The American Economic Review*, vol. 48, no. 3, pp. 261–297, 1958.

[9] A. S. Mello and J. E. Parsons, "Hedging and liquidity," *The Review of Financial Studies*, vol. 13, no. 1, pp. 127–153, 2000.

[10] K. Chan, Y. Tse, and M. Williams, "The relationship between commodity prices and currency exchange rates: Evidence from the futures markets," in *Commodity Prices and Markets, East Asia Seminar on Economics, Volume 20*, pp. 47–71, University of Chicago Press, 2011.

[11] J. Chen, *Essentials of Foreign Exchange Trading*, vol. 44. John Wiley & Sons, 2009.

[12] UPM Pulp, "What is pulp?." `https://www.upmpulp.com/sustainable-pulp/what-is-pulp/`. Accessed: 16.02.2020.

[13] UPM Pulp, "Pulp products." `https://www.upmpulp.com/pulp-products/`, 2020. Accessed: 16.02.2020.

[14] C. Xu and T. Shiina, *Financial Investment, Financial Risk and Risk Management*, pp. 3–11. Singapore: Springer Singapore, 2018.

[15] M. K. Pyles, *The Rocky Marriage of Risk and Return*, pp. 191–240. New York, NY: Springer New York, 2014.

[16] D. G. Luenberger, *Investment Science*. Oxford University Press, 1997.

[17] D. K. Eiteman, A. I. Stonehill, and M. H. Moffett, *Multinational Business Finance, Global Edition.*, vol. Fourteenth edition of *Always Learning*. Pearson, 2016.

[18] J. C. Hull, *Options, Futures, and Other Derivatives, Global Edition*, vol. 9. Pearson Education, 2018.

[19] H. Ekholm and C. Nguyen, "Hedging core and non-core risks: Evidence from forestry and paper industry," Master's thesis, Lund University, 2006.

[20] R. Albuquerque, "Optimal currency hedging," *Global Finance Journal*, vol. 18, no. 1, pp. 16–33, 2007.

[21] J. Okochi, "Commodity hedging: Best practices for modelling commodity exposures.," *Journal of Corporate Treasury Management*, vol. 2, no. 1, pp. 42 – 46, 2008.

[22] O. Boyabatli and L. B. Toktay, "Operational hedging: A review with discussion," *Research Collection Lee Kong Chian School Of Business*, 2004.

[23] C. Géczy, B. A. Minton, and C. Schrand, "Why firms use currency derivatives," *The Journal of Finance*, vol. 52, no. 4, pp. 1323–1354, 1997.

[24] S. Nydahl, "Exchange rate exposure, foreign involvement and currency hedging of firms: some swedish evidence," *European Financial Management*, vol. 5, no. 2, pp. 241–257, 1999.

[25] N. Hagelin, "Why firms hedge with currency derivatives: an examination of transaction and translation exposure," *Applied Financial Economics*, vol. 13, no. 1, pp. 55–69, 2003.

[26] W. Chen, M. Kritzman, and D. Turkington, "Alternative currency hedging strategies with known covariances," *Journal of Investment Management*, vol. 2, pp. 6–24, 2015.

[27] J. Y. Campbell, K. Serfaty-de Mederiros, and L. M. Viceira, "Global currency hedging," *The Journal of Finance*, vol. 65, no. 1, pp. 87–121, 2010.

7 Self assessment

7.1 Project progression

Some changes in the project scope were made along the way. Initially, our objective was to build a hedging tool that the client could use as it is. This was changed since we realized that we needed to focus on finding the best hedging strategy, not to develop an application. Instead, our new goal was to build a hedging model that could be used as proof-of-concept of our method, and the client could then implement the strategy with their own tools. In addition, we were planning to try out hedging using options, but we decided not to do that in order to limit the project scope.

One of the greater risks we initially saw with the project was that we would run out of time to finish the implementation. The probability of this risk was considered high, since it could be caused by a number of different things, team member inactivity or absence, the scope being to wide for the course or imbalanced workload due to communication issues. The team members had different study backgrounds, which caused some problems with the definition of roles. Some effort was made to try and fix these problems but unfortunately they were present throughout the course.

The Covid-19 outbreak was a risk that was impossible to anticipate, and it also caused some problems for this group. When changing to working completely remotely, the productivity decreased at first. Risks related to communication issues with the client were mitigated well thanks to frequent meetings and and communication via Slack. The pandemic did not cause any large problems in this aspect.

The original schedule was changed a bit along the way. The literature review went on in the background during almost the whole project, but still a lot of work was left to be done in the end of the project, when writing the literature review for the report. Data analysis was made in several iterations in the project as more data was received from the client. The study of correlations between pulp prices and exchange rates took up more time than planned and was done simultaneously with developing the hedging tool. We also decided to focus on hedging with forwards and skipped the options. Overall, the project workload was largely shifted towards the last month, and often tasks were done in the last minute (such as writing the reports).

The project execution could be divided into three stages: Data-analysis, coding the hedge simulator and validating different strategies. The first thing done was the hedging simulator, which was adjusted time to time when new data was received. The data-analysis was ongoing throughout the project, but no new findings were made during the last two months. The validation was ongoing for the last month of the project, where we tested hedging with different approaches.

After making some adjustments to the scope of the project, the amount of work was quite suitable for the course. However, the workload was not evenly distributed between the team members. This was in part due to team members' different amounts of other commitments, and struggles to find suitable tasks for everyone.

7.2 Success of the project

The objective of the project remained clear though the project. The project succeeded in finding basic hedges with using a few currencies. We were able to find different factors with which the hedging performance could be adjusted, as the time horizon and how the forward maturities were distributed. Taken into consideration that only two of the team members took part in the implementation (data-analysis and simulating), we settle with the results. We focused on finding something less complex which works, rather than creating a highly sensitive model.

The end result of the project suffered a lot from the half manned implementation. This resulted in half less work and ideas regarding the solution. There was very little literature regarding the topic, since most of them are probably private. Also the iterative approach might not have been the best possible. We did not want to create model which would turn out biased in the future and therefore were too cautious with the models which we tried to create.

7.3 Improvement areas

As stated previously, the team came from different backgrounds which caused some issues. We had problems with splitting up the workload in a fair manner and finding tasks suited to each individual member's skills. Different solution were tried out and some matters were improved, but this remained a large challenge in the project. In addition, the members had varying amounts of other commitments that took up their time, which lead to the workload being shifted towards the end of the course. Discussions about goals and expectations, as well as better scheduling, would have helped alleviate these problems.

Scheduling of tasks could have been done better. The schedule produced in the Project Plan was not used in practice, and at a given time it was hard to say what was the state of the project, what tasks were ongoing, who was doing what, and what was going to be done next. This was, however, improved in the last stage of the project. Additionally, team members had different thoughts about how early before deadlines certain tasks should be started. A discussion about our internal working methods, and everyone committing to the agreed guidelines, could have helped with this problem. We should also have set more subgoals, for when a specified task or set of tasks should be finished. In this way, tracking the project progress would have been easier.

The teaching staff provided us with valuable feedback on the project excursion meetings. We also had one initial meeting with the professor which gave us ideas and input on how to start the project. Later in the course we did not communicate much with the course staff.

The client organization, UPM, supported us throughout the project. We had several meetings to make sure we were on the right track, and where we could ask question about the project. In addition, we communicated through Slack for shorter questions. The client also provided us with additional data as we needed it. To conclude, all communication with UPM was fast and efficient!