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Abstract

This paper analyzes optimal hedge ratios for foreign exchange (FX) rate risk of companies. Our contribution to the literature is twofold: (i) We present a theoretical two-period regret model that allows us to analyze the determinants of the optimal hedge ratio given the outcome of past hedging decisions and future expectations. The model implies that the optimal hedge ratio depends on the past hedge ratio, the past exchange rate return, the expected exchange rate return and the skewness of its distribution, its covariance to the foreign market return, as well as the company's risk and regret aversion. (ii) We test the related model-derived hypotheses on a broad sample of US non-financial companies over the period 1995 to 2015 and find strong evidence for the model's predictions. By adding a dynamic regret approach to the hedging and FX literature we shed further light on the rationale behind selective hedging.

Keywords: Exchange rate exposure; regret aversion; hedging; risk aversion; derivatives

JEL classification: F31; G15; G32; G41

1 Introduction

Standard theory predicts that companies should hedge all market risks. However, there is evidence that companies deviate from this theoretical guidance and refrain from hedging all their associated market risks (e.g. Bodnar et al., 1998; Glaum, 2002). Additionally in the context of currency risk, the empirical evidence of exchange rates significantly affecting stock returns of non-financial companies suggests that there are corporations that do not choose to hedge all their currency risks (e.g. Jorion, 1990; Bodnar and Gentry, 1993), because a full hedge of currency risk is likely to result in an insignificant exposure of currency movements against stock returns of companies. Considering this, the question arises, whether such a selective hedging strategy can still be seen as optimal behavior of companies.[1]

In this light, the behavioral dimension of regret theory can add to the understanding of companies' optimal currency hedging by incorporating the influence of negative utility from ex-post non-optimal decisions.[2] Derived by Bell (1982, 1983) and Loomes and Sugden (1982) and later axiomatized by Sugden (1993) and Quiggin (1994), this normative theory of choice under uncertainty predicts a violation of the transitivity axiom of the expected utility theory framework (von Neumann and Morgenstern, 1947). It differs from Kahneman and Tversky's (1979) prospect theory, as agents – in an attempt to avoid future regret – ex-ante incorporate this feeling of rejoice into their altered preference function to maximize their expected utility under risk. Regret can therefore be defined as the disutility of not having chosen the ex-post optimal alternative. Given this ex-post disutility, it might be optimal not to be fully hedged ex-ante. Thus, regret-induced selective hedging can help to understand currency hedge ratios under 100% and therefore why we find exchange rate exposure at all. Granted that anticipating

[1] See, e.g., Stulz (1996) for a detailed discussion.

[2] Consider an example: Agents of n US company that exports goods to the euro area, hedge all the euro exposure for the next year. Now the US dollar depreciates against the Euro. The decision makers in our considered company experience regret as they have chosen an ex-post suboptimal alternative and therefore realize disutility.

regret, not choosing a full hedge is rational, what is the optimal hedge ratio for companies? Or more precisely, what are the determinants of the hedge ratio in a dynamic setting?

As our first contribution, we extend the static approach of Michenaud and Solnik (2008) to a two-period regret model. Companies are naturally confronted with the need to make decisions in a going concern setting in order to maximize their expected utility and to adjust their behavior as the consequences of their decision can be observed. Modeling this adjusted behavior in an uncertain environment according to previous hedging information, gives us a more realistic understanding of strategic hedging decisions of companies under regret and risk aversion. This dynamic multiperiod model allows us therefore to analyze the determinants of the optimal hedge ratio given the outcome of past hedging decisions and future expectations.

We set up a global end wealth representation and are interested in the part that is foreign trade sensitive with the influencing factors being the foreign business return, the exchange rate and the hedge ratio of each period. These factors affect an overall utility function. The ex-post optimal decision of the included regret term is determined according to a local exporter. Thus, if the local exchange rate depreciates, not being hedged would be optimal. We optimize this utility function, taking the decision of the hedge ratio and the exchange rate of the first period as given and taking into account the expectations of the second period. Using second-order Taylor expansion we obtain an analytical representation of the optimal hedge ratio of the second period that allows us to derive testable hypotheses on its determinants and on respective signs.

The model-implied determinants are the past exchange rate return, the past hedge ratio, the expected future exchange rate return and the skewness of its distribution, its covariance to the foreign business return as well as the company's risk and regret aversion. Analyzing our model with the future business returns and the expected future exchange rate return being zero and the latter having a symmetric distribution, we find that if being unhedged was optimal in the past, the optimal hedge ratio is reduced for higher levels of the past exchange rate return and the past hedge ratio. Not having chosen the optimal decision thus leads to a decrease in the optimal hedge ratio set by an exporting company. Furthermore, for higher levels of risk aversion the optimal hedge ratio increases and for higher levels of regret aversion the optimal hedge ratio decreases.

Relaxing the assumptions in our general model, we again find that that if being unhedged was optimal in the past, the optimal hedge ratio is lower for higher levels of the past exchange rate return given moderate levels of the future exchange rate return, the covariance of the future business return and the future exchange rate returns, and the risk as well as the regret aversion. Equivalently, the optimal hedge ratio is adjusted in the direction of the ex-post optimal past hedge ratio, if the effect is not overcompensated, e.g. by very high levels of the risk aversion relative to the regret aversion or a high covariance. The deviation analysis confirms the economic intuition and the derived optimal hedge ratio of the behavioral model approach. In our second contribution, we then empirically test these derived model's hypotheses.

Financial hedging, operational hedging and pass-through of costs to customers have been identified as the three channels that reduce exposures of companies (Bartram et al., 2010). In order to catch every form of hedging we choose the exchange rate exposure approach of identifying possible sensitivities of stock returns against an exchange rate basket to test the model-derived hypotheses. The lower the hedge ratio, comprising all possible hedging activities, the more exposed the company's share becomes relative to currency movements and vice versa.

In this study, we focus on public US non-financial corporations that have been listed between 1995 and 2015. After accounting for missing data and infrequently traded companies, we are left with 2,137 companies in our considered time frame. For those companies we retrieve weekly stock returns and calculate over 33,000 yearly exchange rate sensitivities. In the next step we explain the yearly exchange rate exposures by a set of company control variables and the model-derived determinants of the hedging ratio. We apply different panel approaches and find strong evidence for the model-derived hypotheses.

The remainder of the paper is organized as follows. Section 2 gives an overview of the related literature. Section 3 introduces the dynamic regret model and analyses the optimal hedging decision. Section 4 gives an overview of the data used in this study and describes the empirical models we established to test the derived hypothesis. Section 4 also presents the empirical findings as well as further robustness checks. Finally, Section 5 provides some concluding comments.

2 Related literature

2.1 Literature on regret

Besides the psychological literature (e.g. Zeelenberg et al., 1996), regret theory has been the subject of finance and investment literature: Braun and Muermann (2004) apply regret to insurance decisions and thereby explain the observed preference for low deductibles. Gollier and Salanié (2006) use a multiplicative, concave utility function in an Arrow-Debreu economy and Muermann et al. (2006) use defined contribution pension schemes to incorporate regret into optimal asset allocation. Muermann and Volkman (2007) show that regret and pride can explain the disposition effect in a dynamic setting. Michenaud and Solnik (2008) apply regret to optimal currency hedging decisions for stock portfolios. Wong (2011) examines the influence of regret aversion on the bank's optimal interest margin. Beilis et al. (2014) study the impact of regret on trading behavior in the foreign exchange market. Qin (2015) uses regret to shed further light on investor behavior and the creation of bubbles. Broll et al. (2015) focus on the behavior of regret-averse firms under exchange rate uncertainty and the impact on trade.

Furthermore, regret has been introduced as a factor to model individual behavior in auctions (e.g. Filiz-Ozbay and Ozbay, 2007), consumer behavior (e.g. Diecidue et al., 2012), production decisions (e.g. Wong, 2014) and many other fields. Bleichrodt et al. (2010) introduce a method to quantitatively measure regret without specifying the shape of the utility function. We add to this literature by developing a dynamic regret model that incorporates both past decisions as well as future expectations for an exporting corporation.

2.2 Literature on theoretical and empirical hedging

The question of whether companies should hedge has been discussed in the theoretic literature over the years. The arbitrage pricing theory by Ross (1976) suggests that hedging policies influence expected returns from a financial asset and therefore the risk-adjusted value of a company if FX risk is priced as a macroeconomic factor (e.g. Ikeda, 1991). The fact that hedging generates economic value also applies to the theory of imperfect markets, which states that companies can increase their market value through hedging activities due to frictions in the Modigliani Miller theorem (Smith and Stulz, 1985; Froot et al., 1993). For example, following such a market imperfection in the form of market segmentation, Adler and Dumas (1983) conclude that hedging is relevant, as the hedge's change in the risk exposure of the company is no longer offset by the value-preserving change of the expected return. Therefore currency hedging could alter the cost of capital for companies if FX risk is priced in the stock market but not in the FX market as a risk premium in forward rates (Jorion, 1991). Such FX risk premia are contingent on the violation of the purchasing-power parity, which has been shown to exist particularly over short time horizons (e.g. Patro et al., 2002). Ergo real returns entail the risk of being invested in a foreign asset and the risk of relative currency change and thus differ between currencies. Particularly under traditional expected utility, if there are no expected future currency movement and therefore no currency speculations, the theoretical optimal currency hedge ratio would be 100%, as currency risk would be associated as pure noise.

To determine the optimal hedge ratio under regret, a mean-variance utility function has often been applied to handle currency exposure. Gardner and Wuilloud (1995) suggest a 50% hedge ratio, as it minimizes the maximum expected regret relative to a completely hedged and unhedged portfolio. They find that such a strategy can be achieved by only a small reduction in mean-variance utility. According to Kinlaw and Kritzman (2009) this simple 50% hedging strategy cannot be seen as optimal, as this strategy will be worse over a long time period and an investor will surely experience regret, resulting in a higher standard deviation at a certain level of regret risk. This suggests a more extreme hedging strategy. Brown (2001) analyzes a single company's hedge ratio. This company anticipates economic exposure for four quarters into the future, and therefore sets a hedge ratio ranging from 60 to 90% in the current quarter. With our model we construct a representation of the determinants governing the hedge ratio, as an attempt to depict all factors influencing the optimal hedge ratio.

2.3 Literature on exchange rate exposure literature

Most studies focus on multinational US companies. These companies reduce their exposure to currency changes through the use of financial derivatives and other hedging instruments, (e.g. Bartram and Bodnar, 2007); financial hedging, operational hedging and pass-through of costs to customers have been identified as the three main channels (Bartram et al., 2010). It is therefore not surprising that there have been mixed results despite the intensive examination of international sales of companies. Jorion (1990) revealed that 15 out of 287 multinational US companies from 1971 to 1987 display significant exchange rate exposure. Jorion (1991) elucidated that exposure varies strongly between industry portfolios. Bartov and Bodnar (1994) did not find a significant relation between US exchange rates and stock returns between 1978 and 1990, whereas Bodnar and Gentry (1993) established that 23% of the examined industry portfolios in the US show significant exposures. Furthermore, Dumas and Solnik (1995) and de Santis and Gérard (1998) show that there are risk premia for exchange rate exposure in international stock returns. Dominguez and Tesar (2006) use firm- and industry-level stock returns as well as different exchange rates to display the exchange rate exposure for eight non-US countries. Priestley and Ødegaard (2007) find that nonlinear exposure effects can improve the exchange rate exposure analysis. Aggarwal and Harper (2010) showed that the market value of domestic and multinational companies are equally exposed.

We empirically test our model's determinants on the exposure of US companies which can be interpreted as a proxy for one minus the current hedge ratio. We thereby add a behavioral dimension to the question of why companies use selective hedging or stock returns to react sensitively to exchange rates. We also shed further light on the analysis of exchange rate exposures with the proxies for the model's determinants such as risk and regret aversion.

3 Model

3.1 General regret model

Bell (1982, 1983) and Loomes and Sugden (1982) incorporate regret in the individual preference set of an investor by postulating the following modified utility function:

$$u(x,y) = v[x] + g\Big(v[x] - v[y]\Big). \tag{1}$$

Their formulation consists of two parts. The first part $v[x]$ is the traditional utility function, with x the chosen alternative. Risk aversion can be constructed by saying that $v[.]$ is monotonically increasing ($v' > 0$; i.e. more x is preferred) and concave ($v'' < 0$). The Arrow-Pratt measure sufficiently constitutes risk aversion using only the first two moments of a utility function: $\lambda = -v''/v'$. Under risk aversion, λ is positive.

The second part is the regret term $+g\Big(v[x] - v[y]\Big)$ with the regret function $g(.)$. We assume $g(.)$ to be monotonically increasing ($g' > 0$; i.e. less regret is preferred) and decreasing concave ($g'' < 0; g''' > 0$), with $g(0) = 0$, which implies regret aversion. The amount of regret is contingent on the difference between the utility of the chosen alternative x and the utility of the forgone alternative y. If x is smaller than y then the experienced regret reduces the overall utility $u(.)$.[3] Using the axiomatization from the original pair-wise choice set of Bell (1982, 1983) and of Loomes and Sugden (1982), Quiggin (1994) shows that the overall utility function can be generalized to a choice set of investments i, yielding outcome x_i, with the consequence that investors only experience regret but not the rejoice:

$$u(x_i) = v[x_i] + kg\left(v[x_i] - \max_j v[x_j]\right). \tag{2}$$

Note that in this specification $g(.)$ cannot be positive. Here investment in the forgone alternative j is the best possible decision that could have been made. If the best decision was made beforehand, the regret function would fall to zero. Furthermore, Bell (1983) added an explicit constant k to generalize the formula. This parameter emphasizes the relative importance of regret relative to the value of the utility function. Investors with $k > 0$ are considered regret averse. For $k = 0$ the overall utility function collapses to a traditional utility function, $u(x_i) = v[x_i]$. Also as developed by Bell (1983), we define a measure regret aversion as $\rho = (-kg''v')/(1 + kg')$. Like with risk aversion, ρ has to be positive for regret aversion or zero for

[3]If x is higher than y the experienced rejoicing increases $u(.)$ by this difference. Mellers et al. (1999) showed that the effect of regret is greater than that of rejoicing. In this paper we only look at regret.

regret neutrality.

3.2 Dynamic regret model

We use the static investment model approach of Michenaud and Solnik (2008) and apply it to the hedging decision of an exporting company. Our model structure consists of three points in time $t_k = k$, with $k = 0, 1, 2$ and two periods in between. The company's operations can be divided into a domestic and foreign business. w_0^d and w_0^f represent the respective present values in $t_0 = 0$ in domestic currency. Consequently, the total value of the firm is $w_0 = w_0^d + w_0^f$. For simplicity, we assume that the present value of domestic business is exogenously given and constant over the considered time periods. The final foreign wealth of the foreign business is dependent on the foreign business return $\tilde{R}$ in terms of the foreign currency and the exchange rate return $\tilde{s}$ in direct quotation, where we use discrete price changes as returns.[4] Leaving out the cross term, the present value of the foreign business after one period is given by $w_1^f = w_0^f\Big(1 + \tilde{R}_1 + \tilde{s}_1\Big)$. Furthermore, the firm can decide to hedge the influence of the exchange rate return $\tilde{s}$ in its final present value by setting a hedge ratio $0 \leq h \leq 1$ representing no hedge and full hedge at its extremes i.e. we do not allow for overhedging or increasing risk. This gives us the present value of the company after period one, i.e. in $t_1 = 1$:

$$w_1 = w_0^d + w_0^f\Big(1 + \tilde{R}_1 + \tilde{s}_1(1 - h_0)\Big). \tag{3}$$

In t_2 the foreign business return R_2 and the exchange rate return of the second period s_2 are realized. Still in t_1 the hedge ratio for the second period h_1 is set. This gives us the present

[4]In contrast to Broll et al. (2015) we do not model the revenue and costs of a company or the current business state at a certain point in time. In our model the business of the exporting company has a present value that also depicts future activity and changes as new information becomes available. As $\tilde{R}$ is the foreign business return in foreign currency, $\tilde{R}$ is positively dependent on $\tilde{s}$. We do not model $\tilde{R}$ explicitly, but allow a covariance of $\tilde{R}$ and $\tilde{s}$ in our model.

value of the company after period two, i.e. in $t_2 = 2$:

$$w_2 = w_0^d + w_0^f \Big(1 + \tilde{R}_1 + \tilde{s}_1(1 - h_0)\Big)\Big(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1)\Big). \tag{4}$$

Without loss of generality we set $w_0^d = 0$ and $w_f^1 = 1$, which is equivalent to a simple linear transformation of w_2. The value of the traditional utility function of the company's present value after two periods $v(w_2)$ can then be stated as: $v\Big[\Big(1 + \tilde{R}_1 + \tilde{s}_1(1 - h_0)\Big)\Big(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1)\Big)\Big]$. Using equation (2), the modified overall utility for two periods in a general form is thus given by:

$$\begin{aligned} u\Big(\tilde{R}_1, \tilde{R}_2, \tilde{s}_1, \tilde{s}_2, h_0, h_1\Big) = & \\ & v\Big[\Big(1 + \tilde{R}_1 + \tilde{s}_1(1 - h_0)\Big)\Big(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1)\Big)\Big] \\ & + kg\Bigg(v\Big[\Big(1 + \tilde{R}_1 + \tilde{s}_1(1 - h_0)\Big)\Big(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1)\Big)\Big] \\ & - \max_{0 \le h_0', h_1' \le 1} v\Big[\Big(1 + \tilde{R}_1 + \tilde{s}_1(1 - h_0')\Big)\Big(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1')\Big)\Big]\Bigg). \end{aligned} \tag{5}$$

The maximum function in the last row of equation (5) is used to calculate the ex-post optimum, taking into account positive or negative outcomes of s_1 and s_2. For an exporter and a positive s_1; h_0 should have been zero, i.e. no hedging in the first period is ex-post optimal. The same holds for a negative s_1, h_0 should have been one, i.e. full hedging in the first period is ex-post optimal.

As we are interested in the dynamic situation where past decisions influence future behavior, the optimal hedge ratio h_1^* in t_1 is the key for our analysis. Thus, the maximization problem that we analyze appears as follows:[5]

$$\max_{h_1} E\Big(u\Big(\tilde{R}_1, \tilde{R}_2, \tilde{s}_1, \tilde{s}_2, h_0, h_1\Big) \mid \tilde{R}_1 = R_1; \tilde{s}_1 = s_1; h_0\Big). \tag{6}$$

We use the positive and negative states of s_1, known in t_1, to analyze the optimal behavior of an exporter separately and consider an increase of s_1 as the first case (s_1^+) and a decrease of s_1 as the second case (s_1^-). To derive a closed-form solution of our model, we differentiate the regret function using piece-wise regret functions. For example, $E_{s_2^+}$ denotes the expectation given an increased state of $\tilde{s}_2$ and vice versa. For case one, the expected value of equation (5) for s_1^+ being positive is given by:

$$\begin{aligned} Eu(.) &= Ev\Big[(1 + R_1 + s_1(1 - h_0))\Big(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1)\Big)\Big] \\ &+ kE_{s_2^+} g\Big(v\Big[(1 + R_1 + s_1(1 - h_0))\Big(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1)\Big)\Big] - v\Big[(1 + R_1 + s_1)\Big(1 + \tilde{R}_2 + \tilde{s}_2\Big)]\Big) \\ &+ kE_{s_2^-} g\Big(v\Big[(1 + R_1 + s_1(1 - h_0))\Big(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1)\Big)\Big] - v\Big[(1 + R_1 + s_1)\Big(1 + \tilde{R}_2\Big)\Big]\Big). \end{aligned} \tag{7}$$

For case two, the expected value of equation (5) for s_1^- being negative is given by:

$$\begin{aligned} Eu(.) &= Ev\Big[(1 + R_1 + s_1(1 - h_0))\Big(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1)\Big)\Big] \\ &+ kE_{s_2^+} g\Big(v\Big[(1 + R_1 + s_1(1 - h_0))\Big(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1)\Big)\Big] - v\Big[(1 + R_1)\Big(1 + \tilde{R}_2 + \tilde{s}_2\Big)\Big]\Big) \\ &+ kE_{s_2^-} g\Big(v\Big[(1 + R_1 + s_1(1 - h_0))\Big(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1)\Big)\Big] - v\Big[(1 + R_1)\Big(1 + \tilde{R}_2\Big)\Big]\Big). \end{aligned} \tag{8}$$

For ease of notation, we decompose $\tilde{R}_2$ and $\tilde{s}_2$ into their means $\bar{R}_2$ and $\bar{s}_2$ and zero means variables r_2 and s_2, respectively: $\tilde{R}_2 = \bar{R}_2 + r_2$ and $\tilde{s}_2 = \bar{s}_2 + s_2$. Furthermore we set $v[0] = v$, $v'[0] = v'$ and so on; $\bar{s}_2^+ = E_{s_2^+}(\tilde{s}_2)$, $\bar{s}_2^- = E_{s_2^-}(\tilde{s}_2)$, $\Sigma s_2 = E\Big(\tilde{s}_2^2\Big)$, $\Sigma s_2^+ = E_{s_2^+}\Big(\tilde{s}_2^2\Big)$ and $\Sigma s_2^- =$

[5] We proof the concavity assumption of our model in Appendix A to provide solutions that deviate from the sole risk-minimization case and that deviate from the optimal hedge ratio just being equal to one, in order to determine the effects of regret aversion under continuous information.

$E_{s_2^-}\left(\tilde{s}_2^2\right)$, whereby Σs_2 is the expectation of squared values of s_2, which is only equivalent to the variance under the zero mean assumption of $\bar{s}_2 = 0$. Also note that $g(0) = 0$ and $\bar{s}_2^+ + \bar{s}_2^- = \bar{s}_2$ as well as $\Sigma s_2^+ + \Sigma s_2^- = \Sigma s_2$, whereby the distribution does not need to be symmetric.

3.3 Model solution: no expected currency change and no foreign business returns

Using the Taylor Expansion around 0 for $v[.]$ and $g(.)$ we can approximate the expected utility functions (7) and (8), discarding moments higher than two. Then, in a first step, we analyze the situation with the expected future exchange rate return $\bar{s}_2$ being zero and having a symmetric distribution. The symmetric distribution of $\bar{s}_2$ leads to: $\Sigma s_2^+ = \Sigma s_2^- = \frac{1}{2}\Sigma s_2$. Furthermore, $\tilde{R}_2$ is zero. These assumptions will be relaxed in a second, more general, analysis of the model. We take the first derivative with respect to h_1 to derive the optimal hedge ratio h_1^*, given the information in t_1.

Proposition 1. *Under continuous regret aversion with no currency-risk premium, symmetric currency return distribution and no foreign business return, the optimal hedge ratio h_1^* is given by:*

For case one, s_1^+:

$$h_1^* = 1 - \frac{1}{2}\frac{\rho}{\rho+\lambda}\frac{1+s_1}{1+s_1(1-h_0)}. \tag{9}$$

For case two, s_1^-:

$$h_1^* = 1 - \frac{1}{2}\frac{\rho}{\rho+\lambda}\frac{1}{1+s_1(1-h_0)}. \tag{10}$$

Proof. See Appendix B. □

For the ex-post optimal hedge ratio in the first period h_0, with zero for s_1^+ and one for s_1^-, we can reproduce the model results of Michenaud and Solnik (2008). The same applies for a zero exchange rate movement in the first period. Equations (9) and (10) collapse to:

$$h_1^* = 1 - \frac{1}{2}\frac{\rho}{\rho + \lambda}. \tag{11}$$

In this special case the optimal hedge ratio h_1^* is always between 50 and 100% depending on the level of regret aversion relative to risk aversion. With large ρ relative to λ, h_1^* converges to 50%. For equal levels of ρ and λ the optimal hedge ratio is 75% and for a low ρ relative to λ, h_1^* reaches 100%.

The fraction $\frac{\rho}{\rho+\lambda}$ similarly influences the overall level of h_1^* of Proposition 1, but now the model result is also dependent on the previous information of s_1 and h_0. The optimal hedge ratio of Proposition 1 varies between 0 to 100% for extreme scenarios of the input parameters. If, for example λ is zero and s_1 as well as h_0 are equal to one for s_1^+, the optimal hedge ratio would be zero due the ex-post worst hedging decision. Again, for a regret aversion of zero, the optimal hedge ratio would be one, equal to the standard theory's full hedge prediction. Thus the risk-averse agent of a company maximizes the expected utility by eliminating the currency exposure.

First we analyze the impact of the past exchange rate return s_1. For case one a higher s_1 results in a lower h_1^* if the optimal decision of $h_0 = 0$ (a higher s_1 is perceived positive by an exporter) has not been taken. For case two, a higher (less negative) s_1 increases h_1^* if the optimal decision of $h_0 = 1$ has not been chosen.

Hypothesis 1. *A higher s_1^+ reduces h_1^* for case one and a less negative s_1^- increases h_1^* for case two, increasing the foreign exchange rate exposure for case one and decreasing the foreign exchange rate exposure for case two.*

The effect of s_1 on h_1^* is intensified by levels of h_0 that are further away from the ex-post optimal decision. A higher h_0 further reduces h_1^* for case one, as h_0 should have been zero and therefore increases the regret. For case two a lower h_0 reduces h_1^*, as h_0 should have been one. Or stated the other way around, a higher h_0 increases h_1^* for case two.

Hypothesis 2. *A higher h_0 reduces h_1^* for case one and increases h_1^* for case two. Thus a higher exchange rate exposure in the first period causes a lower exposure for case one and a higher exposure in case two for the following period.*

As stated above, an increased risk aversion parameter λ leads to a higher h_1^*. Quite intuitively a higher risk aversion reduces willingness to accept the risk resulting from a lower hedge ratio. Consequently, the company will want to be less exposed to exchange rate returns. Also, the higher the level of ρ, the lower the hedge ratio set by a company in order to avoid disutility from an ex-post sub-optimal decision.

Hypothesis 3. *A higher level of risk aversion increases h_1^*, reducing the foreign exchange rate exposure.*

Hypothesis 4. *A higher levels of regret aversion decreases h_1^*, increasing the foreign exchange rate exposure.*

3.4 Model solution: the general case

We now turn to the more general model and therefore drop the assumptions of $\bar{s}_2 = 0$, $\tilde{s}_2$ having a symmetric distribution and no foreign business returns. We again maximize the expected utility function of our model with respect to h_1, given the information in t_1.

Proposition 2. *Under continuous regret aversion the optimal hedge ratio h_1^* is given by:*

For case one, s_1^+:

$$
\begin{aligned}
h_1^* = 1 - & \underbrace{\frac{\rho}{\rho+\lambda}\frac{\Sigma s_2^+(1+s_1)}{\Sigma s_2(1+s_1(1-h_0))}}_{(1)} - \underbrace{\frac{\rho}{\rho+\lambda}\frac{s_1\bar{s}_2 h_0}{\Sigma s_2(1+s_1(1-h_0))}}_{(2)} \\
& - \underbrace{\frac{1}{\rho+\lambda}\frac{\bar{s}_2}{\Sigma s_2(1+s_1(1-h_0))}}_{(3)} + \underbrace{\frac{\lambda}{\rho+\lambda}\left(\frac{\bar{s}_2}{\Sigma s_2} + \frac{cov(r_2,s_2)}{\Sigma s_2(1+s_1(1-h_0))^2}\right)}_{(4)}.
\end{aligned} \tag{12}
$$

For case two, s_1^-:

$$
\begin{aligned}
h_1^* = 1 - & \underbrace{\frac{\rho}{\rho+\lambda}\frac{\Sigma s_2^+}{\Sigma s_2(1+s_1(1-h_0))}}_{(1)} + \underbrace{\frac{\rho}{\rho+\lambda}\frac{s_1\bar{s}_2(1-h_0)}{\Sigma s_2(1+s_1(1-h_0))}}_{(2)} \\
& - \underbrace{\frac{1}{\rho+\lambda}\frac{\bar{s}_2}{\Sigma s_2(1+s_1(1-h_0))}}_{(3)} + \underbrace{\frac{\lambda}{\rho+\lambda}\left(\frac{\bar{s}_2}{\Sigma s_2} + \frac{cov(r_2,s_2)}{\Sigma s_2(1+s_1(1-h_0))^2}\right)}_{(4)}.
\end{aligned} \tag{13}
$$

Proof. See Appendix B. □

The hedge ratio is equal to one minus four terms. We first interpret the four terms and then derive the influence of each model variable on the optimal hedge ratio to formulate the hypotheses of the general model.

For an infinite regret averse agent ($\rho \to \infty$) the first two terms determine the optimal hedge ratio h_1^*, while the third and fourth terms are zero. Therefore, the first two terms can be interpreted as regret terms. The first (regret) term is similar to the model results in Section 3.3 (see equation (9) and (10)). The term differs only by the factor $\Sigma s_2^+/\Sigma s_2$ that we interpret as the skewness of the distribution of s_2.[6] The second (regret) term reduces to zero for the ex-post optimal decision of h_0 (s_1^+: $h_0 = 0$; s_1^-: $h_0 = 1$). The bigger the deviation from the optimal decision in the first period, the greater the influence of this term becomes. Therefore, this term

[6]Recall that if the distribution is symmetric and $\bar{s}_2 = 0$, $\Sigma s_2^+/\Sigma s_2$ is 1/2 (see equation (9) and (10)).

especially gains relevance for ex-post wrong decisions. Furthermore, the influence of this term on h_1^* becomes small for small s_1 and $\bar{s}_2$.

The last two terms are identical for both states of s_1. The influence of the fourth term on h_1^* increases for high levels of λ relative to ρ. This term is mainly influenced by the covariance. Therefore, the fourth term can be interpreted as the covariance term. The third term depends mainly on $\bar{s}_2$. For low levels of λ and ρ the influence of this term increases and thus an agent that is not risk and regret averse will set h_1^* according to the future expectation $\bar{s}_2$. The third term can therefore be said to represent the speculative nature of the decision at hand.

We now turn to the influence of the model variables on h_1^* that we analyzed in Section 3.3. After that we focus on the new variables in the general model. We first analyze the influence of s_1 given that h_0 is ex-post optimal. For case two and the ex-post optimal decision $h_0 = 1$, s_1 no longer influences h_1^*. For case one and $h_0 = 0$, s_1 does not influence the two regret terms. For low levels λ and ρ (or high $\bar{s}_2$), the third speculative term determines the influence of s_1 on h_1^*, and for higher levels λ relative to ρ (or a high covariance) the influence of the fourth covariance term increases.

If h_0 is not ex-post optimal, s_1 influences all four terms. Corresponding to Hypothesis 1, the first regret term decreases h_1^* for more extreme s_1 (higher s_1^+ and lower s_1^-). The same applies to the second regret term for positive $\bar{s}_2$. Also for positive $\bar{s}_2$, the speculative term increases h_1^* for higher s_1^+ and decreases h_1^* for lower s_1^-. More extreme s_1 reduces the speculative effect of $\bar{s}_2$. For negative $\bar{s}_2$ the influence of the second regret term and the speculative term on h_1^* change direction. Lastly, the covariance term decreases h_1^* for higher s_1^+ and increases for lower s_1^-, given a positive covariance.

The overall directional influence of s_1 on h_1^* depends on the size and sign of the model variables such as $\bar{s}_2$, $cov(r_2, s_2)$, λ and ρ.[7] For moderate levels of these model variables the Hypotheses of Section 3.3 can be applied to the general model. In the next section, we provide empirical evidence that the influence on h_1^* stays as stated in Hypotheses 1 to 4 and therefore single model terms or potential extreme values of the model variables do not contradict our predictions.

A higher h_0 decreases h_1^* in case one and increases h_1^* in case two (given a positive $\bar{s}_2$ and covariance) in all but the fourth term. As already stated, the influence of the covariance term will only overcompensate the other terms for very high levels of λ relative to ρ or a high covariance. Analogous to Hypothesis 2, h_1^* is adjusted in the direction of the ex-post optimal decision of h_0 in the first period. This stays the same for negative $\bar{s}_2$ if the second and third term do not overcompensate the first term. As stated in Hypothesis 3 and 4, a higher λ increases h_1^* in all four terms and a higher ρ increases h_1^* in all but the third speculative term (given a positive $\bar{s}_2$ and covariance).

We will now turn to the new variables of the general model. To analyze the influence of $\bar{s}_2$ on h_1^*, we first look at case one with a higher positive $\bar{s}_2$. $\Sigma_{s_2}^+$ increases for a higher $\bar{s}_2$, consequently, h_1^* is decreased by the first term. The same applies to the second and third term. For the fourth term, a higher positive $\bar{s}_2$ increases h_1^*. Hence, if λ is sufficiently low, the fourth term will not overcompensate the first three and a higher $\bar{s}_2$ will decrease h_1^*. For case two the direction of the influence of $\bar{s}_2$ on h_1^* stays the same, as the second term also reduces h_1^* due to negative s_1. Altogether the influence of $\bar{s}_2$ on h_1^* is highly dependent on the level of λ.[8] Furthermore, the

[7]For the derivatives of h_1^* with respect to the model variables see Appendix C.

[8]The following equations show the derivative of Proposition 2 according to $\bar{s}_2$, given the symmetric distribution of $\bar{s}_2$ and the ex-post optimal decision of h_0:

$$s_1^+ : -\frac{1}{\rho+\lambda}\frac{\bar{s}_2}{\Sigma s_2}\left(\frac{1}{1+s_1}-\lambda\right) \text{ and } s_1^- : -\frac{1}{\rho+\lambda}\frac{\bar{s}_2}{\Sigma s_2}\left(1-\lambda\right).$$

As we can see, the critical value that changes the direction of the influence of s_2 on h_1^* is below one for case one and one for case two. This critical value of λ becomes higher for higher levels of ρ and for h_0 that are further impact of $\bar{s}_2$ is decreased by higher values for ρ and Σs_2.[9]

Hypothesis 5. *A higher $\bar{s}_2$ decreases h_1^*, causing a higher foreign exchange rate exposure, if λ is sufficiently low.*

The covariance $cov(r_2, s_2)$ only enters the fourth term and increases h_1^* for positive values and vice versa. Also, the skewness of the distribution of the expected exchange rate only affects the first regret term. For a positive skewed distribution $\Sigma s_2^+/\Sigma s_2$, a regret averse agent will consider high currency returns even occurring with a low probability, setting a lower hedge ratio h_1^* compared to the previous model solution.

Hypothesis 6. *A higher covariance $cov(r_2, s_2)$ increases h_1^*, causing a lower foreign exchange rate exposure.*

Hypothesis 7. *A higher skewed distribution of $\bar{s}_2$ decreases h_1^*, causing a higher foreign exchange rate exposure.*

4 Empirical analysis of US exchange rate exposure

In the next step we aim at empirically testing the above model-derived hypothesis. For this we need a proxy for the level of the optimal hedge ratio. One way would be to take the level of the derivative use relative to a company size factor, such as total assets, as a proxy for the hedge ratio. However, this would not only not capture all forms of financial hedging such as issuing foreign currency debt, but also ignore two other forms of hedging in the FX context: first, operational hedging, e.g. establishing production facilities in foreign currency areas, and secondly pass-through of input costs to customers that occur due to exchange rate changes,

away from the ex-post optimal decision. Until this critical value of λ is reached a positive s_2 will decrease h_1^*.

[9] Note that if $\bar{s}_2$ changes, Σs_2 does too. The derivative of $\frac{\bar{s}_2}{\Sigma s_2}$ in $\bar{s}_2$ can be rewritten as $\frac{\partial}{\partial \bar{s}_2}\frac{\bar{s}_2}{Var(s_2)+(\bar{s}_2)^2} = \frac{Var(s_2)-(\bar{s}_2)^2}{\left(Var(s_2)+(\bar{s}_2)^2\right)^2}$, which is larger than zero if $Var(s_2) > (\bar{s}_2)^2$.

which depends on the companies' market power (Bartram et al., 2010). Bartram et al. (2010) find that companies use all of these hedging forms to reduce their exposure. An only-derivative-based variable will therefore fall short of depicting all the relevant potential hedging channels of a company. We therefore follow the standard approach in the literature and measure the foreign exchange rate exposure as the sensitivity of stock returns to changes in an FX rate. Assuming markets to be sufficiently efficient, this sensitivity – defined later in more detail – represents the foreign exchange rate exposure after all hedging activities. As argued later in Section 4.4, the sensitivity can be seen as a proxy for one minus the hedge ratio for exporters.

4.1 Measuring exchange rate exposure

Measuring foreign exchange rate exposures from equity returns goes back to the linear one-factor model of Adler and Dumas (1984). Considering that the market value of a company represents the present value of its future cash flows, they interpret the sensitivity of stock returns to exchange rate returns in t as the exchange rate exposure γ_i of a company i. Jorion (1991) adds a market factor to account for general market influences. Hence, γ_i measures the residual influence of a change in the exchange rate return after consideration of the market impact. Following Fama and French (1993), we amend the well-known factors small minus big (SMB) and high minus low (HML) to avoid potential biases from return differences between small versus large ($R_{SMB,t}$) and value versus growth stocks ($R_{HML,t}$) in period t (see Huffman et al., 2010; Aggarwal and Harper, 2010). The model looks like the following:

$$R_{i,t} = \alpha_i + \beta_{i,m} R_{m,t} + \beta_{i,SMB} R_{SMB,t} + \beta_{i,HML} R_{HML,t} + \gamma_i R_{FX,t} + \varepsilon_{i,t}. \tag{14}$$

$R_{i,t}$ is the total excess stock return of company i over period t and $R_{m,t}$ is the respective total excess return of the market index. $R_{FX,t}$ represents the return of a trade-weighted exchange rate index against the currencies of a large group of major trading partners over period t.

In terms of data frequency, monthly observations would not provide us with sufficient data points to analyze yearly exchange rate sensitivities without using overlapping moving windows which would induce strong autocorrelation in the estimated parameters. We thus choose weekly observations and estimate yearly sensitivities. The sensitivities γ_i are obtained using a standard OLS estimator with a correction of the standard errors according to Newey and West (1987), whereby the number of lags is obtained from an autocorrelation test.

4.2 Data

In this study, we focus on public US corporations that were listed between 1995 and 2015 and are available in Datastream. We consider both multinational and domestic operating companies. Because multinational companies are directly influenced by exchange rate movements that change the value of their foreign revenues and costs against the value of their home currency, they accordingly adjust expected future cash flows as well as the value of foreign assets and liabilities (Allayannis and Ofek, 2001). US domestic companies, however, can also be exposed to FX-risk, e.g. due to competition with foreign companies that operate in the US, due to their own or competitors' foreign suppliers or due to interest rate and other macro-economic effects that vary with exchange rate changes (Aggarwal and Harper, 2010).

Our dataset is free of survivorship bias. Financial companies are excluded as such enterprises have different business objectives with regard to financial risk-taking and therefore require a separate line of study. To limit a possible effect of infrequent trading, we omit companies that have zero returns for more than ten percent of their weekly data for the whole time frame (see Khoo, 1994). This applies almost exclusively to very small companies that were delisted after a short period of time. Furthermore, we restrict the weekly observations in one year to at least 40 to produce adequate econometric inference. This leaves us with 2,137 companies and over 31,000 firm-years in our considered time frame. For those companies we retrieve weekly total stock returns from Datastream. As a market factor we use Datastream's total US market capitalization index (see Muller and Verschoor, 2006).[10] US Fama-French factors were obtained from the Kenneth R. French's Homepage. The risk-free rate is the one-month Treasury Bill rate.

We use the broad trade-weighted exchange rate provided by the Federal Reserve that nets U.S. export and import shares, as well as third-market competitiveness, by adjusting yearly currency weights and calculate weekly return that we use in Equation (14). We follow the majority of the literature and choose a nominal exchange rate (e.g. Jorion, 1991; Khoo, 1994; Allayannis and Ofek, 2001; El-Masry et al., 2007). Selecting real exchange rates would require the other parameters to be measured in real terms as well (Khoo, 1994) and typically does produce equal results (e.g. Jorion, 1990; Bodnar and Gentry, 1993; Griffin and Stulz, 2001). Furthermore, the relevant corporate data and exchange rates used to the analyze of the exchange rate sensitivities are also obtained from Datastream and the Worldscope Database.

4.3 Descriptive analysis of exchange rate exposure

Table 1 shows the summary statistics of the average yearly exchange rate exposures. The number of companies with a significant exchange rate exposure at the 10% level varies only slightly with peaks in 2002 and 2008. The average of nearly 15% is in line with the exchange rate exposure literature that focuses on US multinationals (e.g. Bartram and Bodnar, 2007). The average size of all exposures (γ_i) is negative and close to zero for most of the years, with an average of -0.064.

[Table 1 about here.]

Figure 1 illustrates the development of average exposures over our sample period. The mean

[10] We also tested several other market factors such as S&P 500, the Fama-French market factor, Russel and Wilshire indices. The use of neither of these indices changed our results.

exposures are close to zero and predominantly negative for most of the observation period. Average exposures vary only slightly over time, but especially in the beginning of our observation period we find phases with high cross-sectional variation and increased values in the tails of the distribution for the 10/90% quantile. All in all, the dataset as well as the estimated exchange rate exposures are in line with the studies in this strand of the literature.

[Figure 1 about here.]

4.4 Explaining exchange rate exposure

In the next step we use the estimated foreign exchange rate exposures to analyze the determinants of the hedge ratio. If a company sets its hedge ratio to 100% the exchange rate exposure would be zero. The lower the hedge ratio, including all possible hedging activities, the more exposed the company becomes relative to currency movements and vice versa. Hence, the exposure is directly linked to the hedge ratio set by a company. As we use the positive estimated exposures to identify potential (net) exporting companies and negative estimated exposures to identify potential (net) importing companies (see e.g. Allayannis and Ofek, 2001; Bartram and Karolyi, 2006; Bartram et al., 2010), a higher exposure corresponds to an increased positive sensitivity for a potential exporting company and a decreased negative sensitivity (increase in absolute value) for a potential importing company. Consequently we use the positive estimated exposure $\hat{\gamma}_{i,j}$ of company i and year j in the following analysis as a proxy for one minus the current hedge ratio, i.e. $1 - h_1^*$ and the negative estimated exposure as a proxy for the hedge ratio, i.e. h_1^*.[11]

[11]Note that as we estimate the exchange rate exposure with an included market factor, the exposure measures the impact of a change in the exchange rate return on company stocks after taking into account the market-wide impact. Thus, the exchange rate exposure must be interpreted as residual exposure. This is why we can only identify companies as potential importing or exporting companies. This is also why we might not necessarily find an exchange rate exposure of zero for a hedge ratio of 100%.

Francis et al. (2017) used the measured exchange rate exposures to explain the influence of managerial risk-taking incentive variables and control variables previously used in this literature. We also adopt this methodology and consider both proxies of the derived model's hypotheses and commonly used company characteristics as explanatory variables in our model. Furthermore, we do not include Hypothesis 6 in our empirical analysis, as there is no economically convincing proxy for both exporters and importers.[12] We thus estimate the following equation:

$$\begin{aligned}\hat{\gamma}_{i,j} = \omega_i + &\phi_1 \; \textit{Past Exchange Rate Returns}_{i,j} + \phi_2 \; \hat{\gamma}_{i,j-1} + \phi_3 \; \textit{Risk Aversion}_{i,j} \\ &+\phi_4 \; \textit{Regret Aversion}_{i,j} + \phi_5 \; \textit{Expected Exchange Rate Returns}_{i,j} \\ &+\phi_7 \; \textit{Skewness}_{i,j} + \phi_{8-13} \; \textit{Controls}_{i,j} + \eta_{i,j}.\end{aligned} \tag{15}$$

We apply two regression designs and use a fixed-effects panel regression with robust and clustered standard errors on the company level when estimating Equation (15) without the lagged exchange rate exposure $\hat{\gamma}_{i,j-1}$. If we include $\hat{\gamma}_{i,j-1}$ we use a dynamic panel estimation, because the unobserved panel-level effects are correlated with the lagged dependent variables by construction, making the standard within-estimator inconsistent. Building upon Hansen (1982) and Holtz-Eakin et al. (1988), Arellano and Bond (1991) developed a consistent one- and two-step generalized method of moments (GMM) estimator. We also use the estimator of Blundell and Bond (1998), which is based on the work of Arellano and Bover (1995), because it performs better if the autoregressive process becomes too persistent or the ratio of the variance of the panel-level effect to the variance of idiosyncratic error becomes large. As the two linear dynamic

[12] As a potential proxy, we first retrieved weekly returns of the market indices of all major US trade partners. We then used the yearly weights of the trade-weighted currency basket to build a foreign market index to account for the foreign market return. Second, we calibrate a bivariate GARCH model with varying conditional correlations and dynamically forecast the average yearly correlations of the foreign market index and the exchange rate returns of the trade-weighted currency basket given the information up to each year. As this potential proxy concentrates on the foreign market to account for the foreign business return it would be plausible to use it for exporting but not for importing companies. The resulting influence of this proxy on h_1^* reflects our model predictions, but as we cannot apply it to all companies in our sample, we do not include it in our analysis.

specifications produce the same results, we apply and only report on the system estimator of Arellano and Bond (1991) and Arellano and Bover (1995), which specifies a level as well as a difference equation and we use the Windmeijer (2005) standard error bias-correction of the two step GMM estimator.[13]

4.5 Influence and proxies of the model-derived variables

In Table 2 we summarize the different effect of the model-derived variables on the foreign exchange rate exposure and their related proxies. Our model in Section 3 is set up for an exporter confronted with exchange rate returns in direct quotation. The deduced effect of the proxies for each hypothesis on the foreign exchange rate exposure is displayed in second and third column.[14]

The intuition of the model's hypotheses can also be applied to an importer by changing that an increased s_1 or $\bar{s}_2$ in direct quotation is perceived as negative and a decreased s_1 or $\bar{s}_2$ as positive. As mentioned above, we use the negative, estimated $\hat{\gamma}_{i,j}$ to identify potential importers, because a positive exchange rate return causes a negative impact on the stock returns for importers. As stated in Section 4.4, we use the positive, estimated exposures as a proxy for one minus the hedge ratio $(1-h_1^*)$ and negative estimated exposures as a proxy for the hedge ratio (h_1^*). Compared to the exporting companies, we thus expect the inverse effect for Hypotheses 3, 4 and 7 and an analogous effect for Hypotheses 1, 2 and 5 regarding the negative exposures of importers.

If we want to analyze all companies at once, we use the absolute values of $|\hat{\gamma}_{i,j}|$ and therefore

[13]Note that based on our model we establish the assumption that higher lags of the dependent variable do not cause endogeneity. Empirically, we also show results for higher lags of the dependent variable. We depict lags up to three, as higher lags do not show a significant influence on the dependent variable.

[14]Note that for Hypothesis 5, the direction of effect is influenced by the value of λ. As stated above, it is reasonable to assume moderate levels of λ for most of the companies. But as the critical values of λ that changes the effective direction of $\bar{s}_2$ is close to one, it is not yet clear which sign the expected exchange rate returns will have. For more risk averse exporters, a positive $\bar{s}_2$ will have a positive impact on h_1^*, seeing the future development more as an increase in risk. It is unlikely that the majority of companies in our sample will see potential opportunities in the form of an expected exchange rate return as an increase in risk or threat to their business.

look at deviations of positive and negative $\hat{\gamma}_{i,j}$ from zero. For Hypotheses 1, 2 and 5 we do not have an expected direction of effect as these influences oppose each other if we consider absolute exposures. We will empirically verify the influence of absolute past exposures and whether the effect of exporters or importers outweighs the other. For Hypothesis 3 we expect an overall negative effect and for Hypotheses 4 and 7 we expect an overall positive effect.

[Table 2 about here.]

4.5.1 Hypothesis 1: past exchange rate returns

As a proxy for s_1, we use yearly exchange rate returns of the trade-weighted currency basket. Bear in mind that if we analyze all companies together, we apply absolute past exchange rate returns.

4.5.2 Hypothesis 2: past hedge ratios

As the proxy for h_0, we use the lagged exchange rate exposure $\hat{\gamma}_{i,j-1}$ to analyze the effect on $\hat{\gamma}_{i,j}$, the proxy for h_1^*. If we include $\hat{\gamma}_{i,j-1}$ we need to use a dynamic panel estimation.

4.5.3 Hypothesis 3: risk aversion

As a proxy for λ, we use discretionary accruals from the modified Jones Model as a proxy for company risk aversion. The modified Jones Model is predominantly used to disclose the earnings management of companies and has been used in the context of exchange rate exposure before (e.g. Chang et al., 2013). The modified Jones Model can easily be calculated using broadly available corporate data. Following Jones (1991), Dechow et al. (1995) amended several company characteristics to account for a change in accruals that is based on the business activities of a company. As a dependent variable we regress total accruals (TA_{it}) for each company i and each year t, for which we use the difference between the income before extraordinary items and operating cash flow relative to the previous year's assets AT_{it-1}, on various company characteristics. Such factors are the relation of one divided by AT_{it-1}, the difference between change sales and change of accounts receivable $\Delta REV_{it} - \Delta AR_{it}$ relative to AT_{it-1} and gross property, plants and equipment PPE_{it} relative to AT_{it-1}. Kothari et al. (2005) added the return on assets ROA_{it} relative to AT_{it-1} to control for a possible correlation between firm performance and accruals, because an unusual business performance could lead to accruals being systematically non-zero. Thus, the modified Jones Model is given by:

$$\begin{aligned} TA_{it}/AT_{it-1} = &\beta_0 + \beta_1(1/AT_{it-1}) + \beta_2(\Delta REV_{it} - \Delta AR_{it})/AT_{it-1} + \beta_3 PPE_{it}/AT_{it-1} \\ &+ \beta_4 ROA_{it}/AT_{it-1} + \epsilon_{it}. \end{aligned} \tag{16}$$

The residual of the fixed-effects regression are the discretionary accruals, the unexplained part of the total accruals that cannot be accounted for by various corporate figure developments.[15] Discretionary accruals are thus connected to risk aversion, as a company with more accruals than justifiable from their corporate data can be considered cautious. Furthermore, Abdel-Khalik (2007) showed that with higher CEO risk aversion the mean rank of earnings volatility decreased. Because CEOs invest a disproportionately large share of their wealth in the equities of their firms, his findings suggest that CEOs seek to smooth earnings over time as a matter of self-interest. Thus more management of earnings is linked to higher risk aversion.

However, as the concepts of risk aversion and earnings management are not explicitly separable, we substantiate this proxy for risk aversion using individual executive characteristics in the robustness checks.[16] Beber and Fabbri (2012) state that younger managers speculate more.

[15] Note that we winsorize 0.5% of the residuals on each end to account for outliners of the modified Jones Model.

[16] We focus on individual executive characteristics, because other variables such as share and option-based executive compensation showed mixed results in identifying risk aversion in various studies. Smith and Stulz (1985) predicted a negative relation between managerial option compensation and derivatives usage for hedging,

They find support for their hypothesis as older CEOs are more conservative in taking active stances on the currency market. We retrieved the ages of the highest ranking executives in our sample from the ExecuComp Database and use this variable as an additional proxy for risk aversion. Furthermore, we use the individual relative risk aversion (RRA) parameter of Brenner (2015), which he calculated by calibrating a subjective option valuation model for option exercising data for U.S. executives. We matched this the RRA-variable for a subset of top executives in our sample using the ExecuComp Database.

4.5.4 Hypothesis 4: regret aversion

There is no generally accepted measure of regret aversion. Brown (2001) suggests a measure to account for the behavioral influence of regret. In this study past gains and losses of the derivative position as a percent of exposure are used to quantify the impact of recent hedging results and therefore may capture the effect of regret towards having under- or over-hedged.[17] This measure is not a proxy for a change in regret aversion but rather tests for the existence of regret – like for zero regret aversion – gains or losses of the previous period related to the exposure of a company should not influence the hedge ratio of a company. Consequently, under an existing influence of regret aversion we should see higher exposures. As the gains and losses of currency derivative usage are only available for a very limited number of companies and years, we show the results of this proxy for a very limited subsample.[18]

Keep in mind that by testing model-derived variables that are directly affected by the regret terms, we control for regret aversion. If there is no regret aversion and ρ equals zero in the simplified model, we should for example not find a significant impact of s_1 or h_0 on h_1^*, as the

i.e. more risk taking, but for example Géczy et al. (1997) did not find evidence for this relation.

[17] As we do not have specific transaction, translation or economic exposures of the companies considered, we use the present foreign sales scaled to the previous period of exchange rate exposure.

[18] We are not aware of any other proxy that directly measures regret aversion.

optimal hedge ratio would decrease to one. In the general model the skewness of the distribution of Σs_2 should not influence h_1^*, as only the first two terms would have an impact on the hedging decision.

4.5.5 Hypothesis 5: expected exchange rate returns

As a proxy for $\bar{s}_2$, we forecast expected exchange rate returns using the trade-weighted currency basket returns in an ARIMA procedure. This approach is not new to the literature on exchange rate exposure. El-Masry et al. (2007) apply ARIMA(1,1,1) to calculate the unexpected change in exchange rates to provide better evidence for the exposure of UK firms. We utilize ARIMA to separate out the expected part of the exchange rate change. We calibrate the ARIMA model using the information up to the end of each year and then dynamically yearly forecast expected changes given also only the information up to the end of each year.[19]

4.5.6 Hypothesis 7: skewness of the distribution

As a proxy for $\Sigma s_2^+/\Sigma s_2$, we perform yearly skewness tests using the weekly observations of the trade-weighted currency index and create a dummy for a positive skewness. We use the previous period skewness as a predictor for the expected distribution of the following period.

4.6 Control variables

In addition to the above-mentioned variables, many others in the literature on exchange rate are reported exposure as having an influence on hedging behavior, some of which we use as control variables. Like most studies in this strand of the literature, we too find a significant influence of the firm size (SIZE). We use the log of total assets. Larger companies use economies of scale to

[19] As our weekly exchange rate returns are stationary, we calculate an ARIMA(1,0,1) model without differencing and set an autoregressive and moving average lag of one due to the AIC criterion.

reduce hedging costs and are more likely to be able to use operational hedging, and thus show a lower exchange rate exposure (e.g. Nance et al., 1993; Dominguez and Tesar, 2006).

Jorion (1990) showed that the level of exposure depends on foreign sales. The ratio of foreign sales to total sales (FOREIGN SALES) indicates potential exposure. Most studies find foreign sales have a negative influence on exposure, meaning that the that more multinational operating companies engage internationally the more they hedge, lowering their exposure. It could also be the case that companies do not adequately react to their higher exposure due to more foreign engagement. We therefore have to established if companies with a higher potential exposure hedge more or less, causing a lower or higher exposure. Following El-Masry et al. (2007) we also add international operating income to total income (INTERN. INC.).[20]

The leverage ratio (LEVERAGE) represents an incentive to counter higher expected distress costs with more hedging activities. An increased leverage ratio should therefore correspond to a decreased exposure (Muller and Verschoor, 2006). Note that a reaction could also be caused by the fact that more highly leveraged companies have riskier equity. Nance et al. (1993) hypothesize that expected costs of financial distress can further be reduced by providing a higher short-term liquidity cushion, which acts as a substitute for hedging. Companies with a higher quick ratio (QUICK) or that maintain a lower dividend per earnings ratio (DIVIDENDS P. E.) have more funds available to meet the cost of adverse foreign exchange rate movements and are thus less obliged to hedge (He and Ng, 1998). According to Froot et al. (1993), firms with higher growth opportunities are more likely to hedge. In an attempt to reduce the cost of external financing, firms with higher growth opportunities have more need to account for their cash-flow volatility. We use research and development expenditures to total sales (R&D SALES)

[20] Note that the influence of the foreign sales or international income ratio on the exposure might be inconclusive if we analyze absolute exposure. The reason is that the influencing direction could differ for positive and negative exchange rate exposure sensitivities. This would e.g. be the case for a higher foreign sales ratio, if we find increased positive exposures and increased (less negative) negative exposures.

as a proxy for growth opportunities. Variables such as book value per share or the foreign assets ratio have been omitted due to their high correlation with the variables already included. As the results of our the control variables are mostly in line with the literature on foreign exchange rate exposure, we concentrate on our model hypothesis in the empirical results.

4.7 Empirical results

We test the general model-derived hypotheses by regressing proxies of the derived foreign exchange rate exposures of the companies considered. In a first step we use a fixed-effects panel regression. The proxy for h_0 is included in a second step using linear dynamic panel regressions. Thirdly, we show the effect of the proxy for ρ on a sub-sample, as past gains and losses from derivative usage are only available for a very limited number of observations. After that we perform additional robustness checks for alternative proxies of the risk aversion parameter λ and different exposure estimations.

Table 3 shows the results of the fixed-effects estimation using the individual companies as the panel variable. In the first regression, absolute exposures and absolute past exchange rate returns are used. After that we analyze exporters and importers as well as positive and negative past exchange rate returns separately in Columns 2 to 5.

[Table 3 about here.]

All the included model-derived variables have a highly significant influence on the absolute values of the exchange rate exposure. We find the expected negative effect of the risk aversion proxy of Hypothesis 3 and the positive effect of the skewness proxy of Hypothesis 7. The proxies of Hypotheses 1 and 5 both show a positive sign, which corresponds to the stronger influence of the exporting companies in our sample.

Turning to the division of all companies into exporters and importers, we find all expected effects of the considered proxies for exporters that are confronted with a positive s_1. The proxy of Hypothesis 3, the discretionary accruals, show the correct negative impact for exporters and the correct positive but not significant impact for importers. The proxy put forward in Hypothesis 5, i.e. the forecasted yearly exchange rate returns, are all significant and show the expected direction of influence for exporters given a λ under the critical value. This suggests that the majority of the companies considered are not too risk averse, as the direction of the effect of λ would otherwise be reversed. Exporters use their expectation of the exchange rate to adjust their hedge ratio towards future development. The proxy in Hypothesis 7, the positive skewness dummy, shows a highly significant positive effect for exporters and a negative effect for importers given a positive s_1 as predicted.

As stated above, if we include the proxy of Hypothesis 2, the lagged exposures, we have to use a linear dynamic panel approach to account for the correlation of the unobserved panel-level effects and the lagged dependent variables. We show the system estimator that specifies both a level as well as a difference equation in Table 4.

[Table 4 about here.]

For the absolute exposures we again find – as predicted – a negative effect for the risk aversion proxy and a positive significant effect for the skewness proxy. The Hypotheses 1 and 5 are still positive, as is the added proxy of the past exposures. The added Hypothesis 2 shows a significant positive effect.

For the subsamples of exporters and importers confronted with positive and negative s_1, the proxy of Hypothesis 1 proxy, i.e. the past yearly exchange rate returns of the trade-weighted currency basket, exhibits the expected direction of influence for exporters. Looking at the proxy in Hypothesis 2, the lagged exposures, we find a negative effect on the current exposure for negative s_1 for exporters and a positive effect for positive s_1 for both exporters and importers, with only the latter being significant.[21] For the risk aversion proxy of Hypothesis 3, we find a significant negative effect for exporters.

We also want to test Hypothesis 4 by including the proxy for regret aversion, i.e. the past gains and losses from derivative usage relative to transaction exposure, as shown in Table 5. Due to the limited availability of this proxy, the sample size is greatly reduced by the inclusion of the regret aversion parameter. As stated above, we do not test the change in regret aversion but the mere existence of regret, which like for zero regret aversion means that the gains or losses in the previous period related to the transaction exposure of a company should not influence its hedge ratio.

[Table 5 about here.]

The proxy for Hypothesis 4 is positive and significant for absolute $\hat{\gamma}_{i,j}$ and exporters confronted with a positive s_1. For the rest of the subsamples we also find the predicted direction of effect. Thus with an existing influence of regret aversion we see higher exposures. Furthermore, the discretionary accruals of Hypothesis 3 show a significant negative impact for absolute exposures and for exporters even after including the regret aversion proxy. We thus confirm that risk and regret aversion are indeed separable effects that can both be found in the exposure of US companies.

The effects of the other hypotheses proxies stay almost exclusively the same. Hypothesis 5 shows us again that the risk aversion is not above the critical value as especially exporting companies still use their future expectation of the exchange rate to benefit from its development. The significance of the proxy for Hypothesis 7 reduces for this sub-sample specification. Note

[21] Since the notion of using only one lag of the exchange rate exposure stems from our two-period regret model, it could be empirically valid to use higher lags if exposures of the previous period significantly influence the current exposure. This appears economically intuitive, because hedging strategies are indeed adjusted but likely not completely changed on a yearly basis. Thus, we also used up to four lags of the exchange rate exposure. For example, we did find a significant effect for h_{-2}, but as the results do not otherwise differ, we refrain from displaying them here.

that for exporters in case one we are able to prove the predicted model effects for all proxies of the model-derived hypotheses.

Overall, we observe the expected effects of our model-derived hypotheses. Especially for exporters, we are able to substantiate significant effects of past exchange rate changes, risk aversion, regret aversion, expected exchange rates and the skewness of its distribution on the hedge ratios of US companies. The influence of the past hedge ratio, measured as the lagged exposures, also shows the expected direction of effect in Table 4 for exporters, however we only observe a significant effect for absolute exposures and importers given a negative s_1.

4.8 Robustness checks

In the next step, we aim to substantiate the risk aversion parameter. The proxy for Hypothesis 3, the discretionary accruals, has been used predominately to look at earnings management. We therefore substitute this variable for the age of the top executives and the RRA parameter of Brenner (2015). Both are only available for a limited number of companies. What we hope to find is that higher levels of both variables has a negative effect on the absolute exposure of companies. Companies with a higher risk aversion are likely to be more cautious and set an overall higher hedge ratio.

[Table 6 about here.]

In Table 6, we see that the effect of age of the top executives is negative at the 10% significance level for the current exposure. The negative effect stays the same, as expected, for exporters and is positive for importers confronted with a negative s_1. Our findings therefore support the hypothesis of Beber and Fabbri (2012) that older CEOs are more conservative in taking active stances on the currency market. The RRA parameter of Brenner (2015) also exhibits a negative but not significant influence on the absolute exposure. Corresponding to the age and the RRA parameter of the top executives of the companies considered, the discretionary accruals show a continuous negative effect on the absolute exposure and are even more significant for various sample specifications.

Furthermore, we show that our results are robust against various estimations techniques of the exchange rate exposure. We test the impact of non-linear exchange rate exposure using quadratic exchange rate returns and a local polynomial non-parametric estimation of the exchange rate exposure. Non-linear exchange rate exposure might be able to depict the actual exposure of companies better, if cash flows or the default risk of the selected companies do not linearly depend on the exchange rate returns (see e.g. Priestley and Ødegaard, 2007). A foreign customer could, for example, default on a payment, due to currency appreciation that increases the price of the payments demanded.

One other estimation technique in the literature on exchange rate exposure is the orthogonalization of the market factor against the exchange rate returns to account for a possible existing collinearity between the market factor and the exchange rate returns. If parts of the exchange rate risk is already measured by the market factor, a estimation including both could produce less significant results regarding the exposures of the companies in our sample. This is why only the part of the market factor that cannot be explained by the exchange rate returns is often used.[22]

Liu et al. (2015), on the other hand criticize this widely used technique and show that it creates inconsistent standard error estimates. They suggest omitting the market factor as a regressor in the first place. If we only include the trade-weighted currency index as a regressor to explain the stock returns – as with the model of Adler and Dumas (1984) – the average yearly exposures are significant in 30% of all cases and average size of the exposure increases to minus

[22]We also tested our model using the orthogonalized exposure estimation and obtain similar results.

one.

Note that the volatility of the exposures also increases if we apply the model specification of Adler and Dumas (1984) that does not control for a market-wide currency impact. As we use the sign of the exposure estimation to distinguish between potential exporting and importing companies, the model results become much more volatile as companies' exposure switches signs partly only because of these omitted overall market reactions. To better identify companies, as potential exporting or importing companies, we take the effect of the added market factor in our main analysis into account and leave the market factor in the estimation.

In Table 7 we use the absolute exposures of the non-linear estimation of the quadratic and non-parametric specification and the absolute exposures with the omitted market factor and display the results using the fixed-effects regression (FE) and linear dynamic panel regression if h_0 is included. We find that the risk aversion proxy of Hypothesis 3 is negative for all exposure estimations and the skewness proxy of Hypothesis 7 is positive and significant for the two non-linear exposure estimation techniques.

[Table 7 about here.]

In Table 8 we reproduce the results of Table 7 but include the proxy for regret aversion of Hypothesis 4. The discretionary accruals of Hypothesis 3 still have a negative impact on the absolute exposures over all estimation specifications. The added proxy for ρ is highly significant and positive as expected for almost all estimation specifications.

[Table 8 about here.]

To further substantiate our findings, we also show the linear dynamic panel results of the model hypotheses for non-linear, quadratic exposure estimation and the estimation without a market factor for the exporters and importers confronted with a positive and negative s_1.[23] In doing so we display the results with and without a regret aversion parameter. In Table 9 we see that the non-linear, quadratic exposure estimation does play a role when analyzing the proxies of our hypotheses.

[Table 9 about here.]

In Table 10 we display the linear dynamic panel results without a market factor. For the model without the regret aversion parameter, we now find many more importers than exporters due to more negative exposures. Even with this exposure estimation, the proxies for Hypotheses 3 and 4 largely match our predictions. The expected exchange rate proxy of Hypothesis 5 is now positive for all subsamples. For Hypothesis 2 we are now unable to substantiate the negative effect of h_0 for positive s_1.

[Table 10 about here.]

5 Concluding Remarks

In this paper we analyze dynamic regret in the context of currency hedging. We develop a two period regret model, based on the static approach for investment decisions by Michenaud and Solnik (2008), that allows us to analyze the determinants of the optimal hedge ratio on the basis of the outcome of past hedging decisions and future expectations. Using information on previous periods and inferred expectations of future periods, we obtain an analytical representation of the current hedging decision that allows us to derive testable hypotheses on the hedge ratio's determinants and on its respective signs. The model implies that the past exchange rate return, the past hedge ratio, the expected future exchange rate return and the skewness of its

[23]For the non-parametric exposure estimation, the direction of effect does not change compared to our main results in Table 4. These results are thus displayed in Appendix D.

distribution, its covariance to the foreign market return as well as the company's risk and regret aversion all influence a company's hedging decisions, which therefore deviate from a full hedge scenario.

We test the model-implied hypotheses for a large sample of public US non-financial corporations that were listed between 1995 and 2015. To represent all possible hedging activities we estimate yearly exchange rate exposures per company and use them as a proxy of one minus the hedge ratio. For each hypothesis, we develop proxies to test the model-derived effects and apply the exchange rate exposure. Our findings strongly support the influence of regret aversion and all other hypotheses on the hedging decision of companies even after controlling for a large number of company characteristics such as size, foreign sales, leverage, liquidity and growth measures.

More specifically, we find evidence that the companies in our sample decrease their hedge ratio for positively perceived past exchange rate returns and do the opposite in response to negatively perceived past experience. The past hedge ratio also causes an adoption of the current hedge ratio, whether the ex-post optimal decision in the previous period was reached or not. Different specifications of risk aversion all confirm the economically intuitive positive effect of a higher risk aversion on the hedge ratio set by the companies considered. In addition to the effect of variables like the skewness of the distribution of the expected exchange rate – that can only influence the hedge ratio if there is regret aversion – we can also verify the effect of regret using a proxy that includes past gains and losses of derivative usage. Furthermore, we confirm the positive influence of the expected exchange rate on the hedge ratio especially for exporters. Companies in our sample take active views of the future and use these expectations to adjust their optimal behavior.

A limitation of our model is the restriction of only two periods. The effect of the past hedge ratios is merely adapted periodically but might show more persistent effects than our model predicts. The implications and the model itself could be generalized due to its general and closed formulation, increasing the complexity of the solution. The same applies to other model assumptions, such as the omission of the cross-term of the foreign market return and the exchange rate return. For the empirical analysis, more detailed data – like with the study of Brown (2001) – about the explicit hedging decision and for how many periods in the future the hedge ratio is set, would enable us to observe effects of regret aversion and its change over time directly. This would reduce the number of proxies that are necessary to analyze the effects on the hedging decision and provide more direct evidence for selective hedging.

Appendix A Concavity of $Eu(.)$ with respect to h_1 in t_1

To provide the concavity of $Eu(.)$, we take the first two derivatives of $u(.)$ with respect to h_1 in t_1 with γ being $(1 + R_1 + s_1(1 - h_0))$:

$$u(R_1, \tilde{R}_2, s_1, \tilde{s}_2, h_0, h_1) =$$
$$v[\gamma(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))] + kg\Big(v[\gamma(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))] - v[max\{\gamma(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))\}]\Big).$$

The first derivative with respect to h_1:

$$\frac{\partial u(.)}{\partial h_1} = -\tilde{s}_2\gamma v' - \tilde{s}_2\gamma kg' \times v'.$$

With $v'[.] = v'[\gamma(1+\tilde{R}_2+\tilde{s}_2(1-h_1))]$, for s_1 being positive $g'\Big(.\Big) = g\Big(v[\gamma(1+\tilde{R}_2+\tilde{s}_2(1-h_1))] - v[(1+R_1+s_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big)$ if s_2 is positive and $g'\Big(.\Big) = g\Big(v[\gamma(1+\tilde{R}_2+\tilde{s}_2(1-h_1))] - v((1+R_1+s_1)(1+\tilde{R}_2))\Big)$ if s_2 is negative and for s_1 being negative $g'\Big(.\Big) = g\Big(v[\gamma(1+\tilde{R}_2+\tilde{s}_2(1-h_1))] - v[(1+R_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big)$ if s_2 is positive and $g'\Big(.\Big) = g\Big(v[\gamma(1+\tilde{R}_2+\tilde{s}_2(1-h_1))] - v((1+R_1)(1+\tilde{R}_2))\Big)$ if s_2 is negative. Therefore $\frac{\partial u(.)}{\partial h_1}$ is zero for $s_2 = 0$.

The second derivative with respect to h_1:

$$\frac{\partial^2 u(.)}{\partial h_1^2} = \tilde{s}_2^2\gamma^2 v'' - \tilde{s}_2\gamma kg'(-\tilde{s}_2\gamma kg'' \times v'^2 - \tilde{s}_2\gamma kg'v'') = \tilde{s}_2^2\gamma^2(v''(1 + k^2g') + v'^2k^2g'').$$

The second derivative is negative if v' and g' are positive (more wealth and less regret) and if v" and g" are negative (risk and regret aversion) for all values of R_1, $\tilde{R}_2$, s_1, $\tilde{s}_2$, h_0, h_1. With $v'[.]$ and $v''[.]$ being valued at $\gamma(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))$ and $g'\Big(.\Big)$ for s_1 being positive at $v[\gamma(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))] - v[(1 + R_1 + s_1)(1 + \tilde{R}_2 + \tilde{s}_2)]$ if s_2 is positive and $v[\gamma(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))] - v((1 + R_1 + s_1)(1 + \tilde{R}_2))$ if s_2 is negative and for s_1 being negative at $v[\gamma(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))] - v[(1 + R_1)(1 + \tilde{R}_2 + \tilde{s}_2)]$ if s_2 is positive and $v[\gamma(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))] - v((1 + R_1)(1 + \tilde{R}_2))$ if s_2 is negative.

Therefore, the second derivative of $Eu(.)$ is also negative as:

$$\frac{\partial^2 Eu(.)}{\partial h_1^2} = E\frac{\partial^2 u(.)}{\partial h_1^2} = E\Big(\tilde{s}_2^2\gamma^2(v''(1 + k^2g') + v'^2k^2g'')\Big).$$

Appendix B General model solution

The utility function with regret aversion in t_1 is given by:

$$
\begin{aligned}
&u(R_1, \tilde{R}_2, s_1, \tilde{s}_2, h_0, h_1) = \\
&\qquad v[(1 + R_1 + s_1(1 - h_0))(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))]+ \\
&\qquad kg\Big(v[(1 + R_1 + s_1(1 - h_0))(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))] \\
&\qquad - v[max\{(1 + R_1 + s_1(1 - h_0))(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))\}]\Big)-
\end{aligned}
$$

Case 1: for s_1^+ in t_1: h_0 should have been 0 (no hedging from t_0 to t_1 optimal)

$$
\begin{aligned}
&Eu = Ev[(1 + R_1 + s_1(1 - h_0))(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))]+ \\
&kE_{s_2^+} g\Big(v[(1 + R_1 + s_1(1 - h_0))(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))] - v[(1 + R_1 + s_1)(1 + \tilde{R}_2 + \tilde{s}_2)]\Big)+ \\
&kE_{s_2^-} g\Big(v[(1 + R_1 + s_1(1 - h_0))(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))] - v((1 + R_1 + s_1)(1 + \tilde{R}_2))\Big).
\end{aligned} \tag{17}
$$

Case 2: for s_1^- in t_1: h_0 should have been 1 (full hedging from t_0 to t_1 optimal)

$$
\begin{aligned}
&Eu = Ev[(1 + R_1 + s_1(1 - h_0))(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))]+ \\
&kE_{s_2^+} g\Big(v[(1 + R_1 + s_1(1 - h_0))(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))] - v[(1 + R_1)(1 + \tilde{R}_2 + \tilde{s}_2)]\Big)+ \\
&kE_{s_2^-} g\Big(v[(1 + R_1 + s_1(1 - h_0))(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))] - v[(1 + R_1)(1 + \tilde{R}_2)]\Big).
\end{aligned} \tag{18}
$$

Using the Taylor Expansion around 0 for v[.] and g$\Big(.\Big)$ we can approximate the expected utility function (17) and (18) in t_1 discarding moments higher than two. $\tilde{R}_2$ can be separated into a random variable $\tilde{r}_2$ and $\bar{R}_2$ with zero mean ($E(R_2^2) = \Sigma r_2$). In t_1 we know R_1, h_0 and s_1, therefore $cov(r_2, s_1) = 0$, $cov(R_1, s_2) = 0$ and $cov(R_1, s_1) = 0$. The expected value function in t_1 therefore is:

$$
\begin{aligned}
&Ev[(1 + R_1 + s_1(1 - h_0))(1 + \tilde{R}_2 + \tilde{s}_2(1 - h_1))] \approx \\
&v[0] + v'[0]\Big(1 + R_1 + r_2 + R_1 r_2 + s_1(1 - h_0) + \bar{s}_2(1 - h_1) + s_1\bar{s}_2(1 - h_0)(1 - h_1)\Big)+ \\
&\frac{1}{2}v''[0]\Big(1 + 2R_1 + R_1^2 + 2r_2 + \Sigma r_2 + 4R_1 r_2 + 2R_1\Sigma r_2 + 2R_1^2 r_2 + R_1^2\Sigma r_2 \\
&+ 2s_1(1 - h_0) + 2\bar{s}_2(1 - h_1) + s_1^2(1 - h_0)^2 + \Sigma s_2(1 - h_1)^2 \\
&+ 4s_1\bar{s}_2(1 - h_0)(1 - h_1) + 2s_1^2\bar{s}_2(1 - h_0)^2(1 - h_1) + 2s_1\Sigma s_2(1 - h_0)(1 - h_1)^2 \\
&+ s_1^2\Sigma s_2(1 - h_0)^2(1 - h_1)^2 + 2cov(r_2, s_2)(1 - h_1)\Big).
\end{aligned} \tag{19}
$$

For Case 1, expanding the expected regret function, over s_2^+:

$$kE_{s_2^+}g\Big(v[(1+R_1+s_1(1-h_0))(1+\tilde{R}_2+\tilde{s}_2(1-h_1))] - v[(1+R_1+s_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big) \approx$$
$$kg\Big(0\Big) + kE_{s_2^+}g'\Big(0\Big)\Big(v[.] - v[(1+R_1+s_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big)+$$
$$\frac{1}{2}kE_{s_2^+}g''\Big(0\Big)\Big(v[.] - v[(1+R_1+s_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big)^2.$$

$$E\Big(v[.] - v[(1+R_1+s_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big) \approx$$
$$v'[0]\Big(1+R_1+r_2+R_1r_2+s_1(1-h_0)+\bar{s}_2(1-h_1)+s_1\bar{s}_2(1-h_0)(1-h_1)$$
$$-(1+R_1+s_1)(1+r_2+\bar{s}_2)\Big)+$$
$$\frac{1}{2}v''[0]\Big(1+2R_1+R_1^2+2r_2+\Sigma r_2+4R_1r_2+2R_1\Sigma r_2+2R_1^2r_2+R_1^2\Sigma r_2$$
$$+2s_1(1-h_0)+2\bar{s}_2(1-h_1)+s_1^2(1-h_0)^2+\Sigma s_2(1-h_1)^2$$
$$+4s_1\bar{s}_2(1-h_0)(1-h_1)+2s_1^2\bar{s}_2(1-h_0)^2(1-h_1)+2s_1\Sigma s_2(1-h_0)(1-h_1)^2$$
$$+s_1^2\Sigma s_2(1-h_0)^2(1-h_1)^2+2cov(r_2,s_2)(1-h_1)-(1+R_1+s_1)^2(1+r_2+\bar{s}_2)^2\Big)$$

$$E\Big(v[.] - v[(1+R_1+s_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big)^2 \approx$$
$$v'^2[0]\Big(s_1^2h_0^2+\Sigma s_2h_1^2+2s_1\bar{s}_2h_0h_1-2s_1^2\bar{s}_2(-h_0^2-h_0h_1+h_0^2h_1)-2s_1\Sigma s_2(-h_0h_1-h_1^2+h_0h_1^2)$$
$$+s_1^2\Sigma s_2(-h_0-h_1+h_0h_1)^2\Big)$$

This gives us the expected regret function over s_2^+:

$$\begin{aligned}
&kE_{s_2^+}g\Big(v[(1+R_1+s_1(1-h_0))(1+\tilde{R}_2+\tilde{s}_2(1-h_1))] - v[(1+R_1+s_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big) \approx\\
&kg\Big(0\Big)+kg'\Big(0\Big)v'[0]\Big(1+R_1+r_2+R_1r_2+s_1(1-h_0)+\bar{s}_2^+(1-h_1)\\
&+s_1\bar{s}_2^+(1-h_0)(1-h_1)-(1+R_1+s_1)(1+r_2+\bar{s}_2^+)\Big)+\\
&\frac{1}{2}kg'\Big(0\Big)v''[0]\Big(1+2R_1+R_1^2+2r_2+\Sigma r_2+4R_1r_2+2R_1\Sigma r_2+2R_1^2r_2+R_1^2\Sigma r_2\\
&+2s_1(1-h_0)+2\bar{s}_2^+(1-h_1)+s_1^2(1-h_0)^2+\Sigma s_2^+(1-h_1)^2\\
&+4s_1\bar{s}_2^+(1-h_0)(1-h_1)+2s_1^2\bar{s}_2^+(1-h_0)^2(1-h_1)+2s_1\Sigma s_2^+(1-h_0)(1-h_1)^2\\
&+s_1^2\Sigma s_2^+(1-h_0)^2(1-h_1)^2+2cov(r_2,s_2^+)(1-h_1)-(1+R_1+s_1)^2(1+r_2+\bar{s}_2^+)^2\Big)+\\
&\frac{1}{2}kg''\Big(0\Big)v'^2[0]\Big(s_1^2h_0^2+\Sigma s_2^+h_1^2+2s_1\bar{s}_2^+h_0h_1-2s_1^2\bar{s}_2^+(-h_0^2-h_0h_1+h_0^2h_1)\\
&-2s_1\Sigma s_2^+(-h_0h_1-h_1^2+h_0h_1^2)+s_1^2\Sigma s_2^+(-h_0-h_1+h_0h_1)^2\Big).
\end{aligned} \tag{20}$$

For Case 1, expanding the expected regret function, over s_2^-:

$$kE_{s_2^+}g\Big(v[(1+R_1+s_1(1-h_0))(1+\tilde{R}_2+\tilde{s}_2(1-h_1))]-v[(1+R_1+s_1)(1+\tilde{R}_2)]\Big)\approx$$
$$kg\Big(0\Big)+kE_{s_2^-}g'\Big(0\Big)\Big(v[.]-v[(1+R_1+s_1)(1+\tilde{R}_2)]\Big)+$$
$$\frac{1}{2}kE_{s_2^-}g''\Big(0\Big)\Big(v[.]-v[(1+R_1+s_1)(1+\tilde{R}_2)]\Big)^2.$$

$$E\Big(v[.]-v[(1+R_1+s_1)(1+\tilde{R}_2)]\Big)\approx$$
$$v'[0]\Big(1+R_1+r_2+R_1r_2+s_1(1-h_0)+\bar{s}_2(1-h_1)+s_1\bar{s}_2(1-h_0)(1-h_1)$$
$$-(1+R_1+s_1)(1+r_2)\Big)$$
$$\frac{1}{2}v''[0]\Big(1+2R_1+R_1^2+2r_2+\Sigma r_2+4R_1r_2+2R_1\Sigma r_2+2R_1^2r_2+R_1^2\Sigma r_2$$
$$+2s_1(1-h_0)+2\bar{s}_2(1-h_1)+s_1^2(1-h_0)^2+\Sigma s_2(1-h_1)^2$$
$$+4s_1\bar{s}_2(1-h_0)(1-h_1)+2s_1^2\bar{s}_2(1-h_0)^2(1-h_1)+2s_1\Sigma s_2(1-h_0)(1-h_1)^2$$
$$+s_1^2\Sigma s_2(1-h_0)^2(1-h_1)^2+2cov(r_2,s_2)(1-h_1)-(1+R_1+s_1)^2(1+r_2)^2\Big)$$

$$E\Big(v[.]-v[(1+R_1+s_1)(1+\tilde{R}_2)]\Big)^2\approx$$
$$v'^2[0]\Big(s_1^2h_0^2+\Sigma s_2(1-h_1)^2-2s_1\bar{s}_2h_0(1-h_1)-2s_1^2\bar{s}_2h_0(1-h_0)(1-h_1)$$
$$+2s_1\Sigma s_2(1-h_0)(1-h_1)^2+s_1^2\Sigma s_2(1-h_0)^2(1-h_1)^2\Big)$$

This gives us the expected regret function over s_2^-:

$$\begin{aligned}
&kE_{s_2^+}g\Big(v[(1+R_1+s_1(1-h_0))(1+\tilde{R}_2+\tilde{s}_2(1-h_1))]-v[(1+R_1+s_1)(1+\tilde{R}_2)]\Big)\approx\\
&kg\Big(0\Big)+kg'\Big(0\Big)v'[0]\Big(1+R_1+r_2+R_1r_2+s_1(1-h_0)+\bar{s_2^-}(1-h_1)\\
&+s_1\bar{s_2^-}(1-h_0)(1-h_1)-(1+R_1+s_1)(1+r_2)\Big)+\\
&\frac{1}{2}kg'\Big(0\Big)v''[0]\Big(1+2R_1+R_1^2+2r_2+\Sigma r_2+4R_1r_2+2R_1\Sigma r_2+2R_1^2r_2+R_1^2\Sigma r_2\\
&+2s_1(1-h_0)+2\bar{s_2^-}(1-h_1)+s_1^2(1-h_0)^2+\Sigma s_2^-(1-h_1)^2\\
&+4s_1\bar{s_2^-}(1-h_0)(1-h_1)+2s_1^2\bar{s_2^-}(1-h_0)^2(1-h_1)+2s_1\Sigma s_2^-(1-h_0)(1-h_1)^2\\
&+s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1)^2+2cov(r_2,s_2^-)(1-h_1)-(1+R_1+s_1)^2(1+r_2)^2\Big)+\\
&\frac{1}{2}kg''\Big(0\Big)v'^2[0]\Big(s_1^2h_0^2+\Sigma s_2^-(1-h_1)^2-2s_1\bar{s_2^-}h_0(1-h_1)-2s_1^2\bar{s_2^-}h_0(1-h_0)(1-h_1)\\
&+2s_1\Sigma s_2^-(1-h_0)(1-h_1)^2+s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1)^2\Big).
\end{aligned}\tag{21}$$

For Case 2, expanding the expected regret function, over s_2^+:

$$kE_{s_2^+}g\Big(v[(1+R_1+s_1(1-h_0))(1+\tilde{R}_2+\tilde{s}_2(1-h_1))]-v[(1+R_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big)\approx$$
$$kg\Big(0\Big)+kE_{s_2^-}g'\Big(0\Big)\Big(v[.]-v[(1+R_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big)+$$
$$\frac{1}{2}kE_{s_2^-}g''\Big(0\Big)\Big(v[.]-v[(1+R_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big)^2.$$

$$E\Big(v[.]-v[(1+R_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big)\approx$$
$$v'[0]\Big(1+R_1+r_2+R_1r_2+s_1(1-h_0)+\bar{s}_2(1-h_1)+s_1\bar{s}_2(1-h_0)(1-h_1)$$
$$-(1+R_1)(1+r_2+\bar{s}_2)\Big)$$
$$\frac{1}{2}v''[0]\Big(1+2R_1+R_1^2+2r_2+\Sigma r_2+4R_1r_2+2R_1\Sigma r_2+2R_1^2r_2+R_1^2\Sigma r_2$$
$$+2s_1(1-h_0)+2\bar{s}_2(1-h_1)+s_1^2(1-h_0)^2+\Sigma s_2(1-h_1)^2$$
$$+4s_1\bar{s}_2(1-h_0)(1-h_1)+2s_1^2\bar{s}_2(1-h_0)^2(1-h_1)+2s_1\Sigma s_2(1-h_0)(1-h_1)^2$$
$$+s_1^2\Sigma s_2(1-h_0)^2(1-h_1)^2+2cov(r_2,s_2)(1-h_1)-(1+R_1)^2(1+r_2+\bar{s}_2)^2\Big)$$

$$E\Big(v[.]-v[(1+R_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big)^2\approx$$
$$v'^2[0]\Big(s_1^2(1-h_0)^2+\Sigma s_2h_1^2-2s_1\bar{s}_2(1-h_0)h_1+2s_1^2\bar{s}_2(1-h_0)^2(1-h_1)$$
$$-2s_1\Sigma s_2(1-h_0)(1-h_1)h_1+s_1^2\Sigma s_2(1-h_0)^2(1-h_1)^2\Big)$$

This gives us the expected regret function over s_2^+:

$$\begin{aligned}
&kE_{s_2^+}g\Big(v[(1+R_1+s_1(1-h_0))(1+\tilde{R}_2+\tilde{s}_2(1-h_1))]-v[(1+R_1)(1+\tilde{R}_2+\tilde{s}_2)]\Big)\approx\\
&kg\Big(0\Big)+kg'\Big(0\Big)v'[0]\Big(1+R_1+r_2+R_1r_2+s_1(1-h_0)+\bar{s}_2^+(1-h_1)\\
&+s_1\bar{s}_2^+(1-h_0)(1-h_1)-(1+R_1)(1+r_2+\bar{s}_2^+)\Big)\\
&\frac{1}{2}kg'\Big(0\Big)v''[0]\Big(1+2R_1+R_1^2+2r_2+\Sigma r_2+4R_1r_2+2R_1\Sigma r_2+2R_1^2r_2+R_1^2\Sigma r_2\\
&+2s_1(1-h_0)+2\bar{s}_2^+(1-h_1)+s_1^2(1-h_0)^2+\Sigma s_2^+(1-h_1)^2\\
&+4s_1\bar{s}_2^+(1-h_0)(1-h_1)+2s_1^2\bar{s}_2^+(1-h_0)^2(1-h_1)+2s_1\Sigma s_2^+(1-h_0)(1-h_1)^2\\
&+s_1^2\Sigma s_2^+(1-h_0)^2(1-h_1)^2+2cov(r_2,s_2^+)(1-h_1)-(1+R_1)^2(1+r_2+\bar{s}_2^+)^2\Big)+\\
&\frac{1}{2}kg''\Big(0\Big)v'^2[0]\Big(s_1^2(1-h_0)^2+\Sigma s_2^+h_1^2-2s_1\bar{s}_2^+(1-h_0)h_1+2s_1^2\bar{s}_2^+(1-h_0)^2(1-h_1)\\
&-2s_1\Sigma s_2^+(1-h_0)(1-h_1)h_1+s_1^2\Sigma s_2^+(1-h_0)^2(1-h_1)^2\Big).
\end{aligned}\tag{22}$$

For Case 2, expanding the expected regret function, over s_2^-:

$$kE_{s_2^+}g\Big(v[(1+R_1+s_1(1-h_0))(1+\tilde{R}_2+\tilde{s}_2(1-h_1))]-v[(1+R_1)(1+\tilde{R}_2)]\Big)\approx$$
$$kg\Big(0\Big)+kE_{s_2^-}g'\Big(0\Big)\Big(v[.]-v[(1+R_1)(1+\tilde{R}_2)]\Big)+$$
$$\frac{1}{2}kE_{s_2^-}g''\Big(0\Big)\Big(v[.]-v[(1+R_1)(1+\tilde{R}_2)]\Big)^2.$$

$$E\Big(v[.]-v[(1+R_1)(1+\tilde{R}_2)]\Big)\approx$$
$$v'[0]\Big(1+R_1+r_2+R_1r_2+s_1(1-h_0)+\bar{s}_2(1-h_1)+s_1\bar{s}_2(1-h_0)(1-h_1)$$
$$-(1+R_1)(1+r_2)\Big)$$
$$\frac{1}{2}v''[0]\Big(1+2R_1+R_1^2+2r_2+\Sigma r_2+4R_1r_2+2R_1\Sigma r_2+2R_1^2r_2+R_1^2\Sigma r_2$$
$$+2s_1(1-h_0)+2\bar{s}_2(1-h_1)+s_1^2(1-h_0)^2+\Sigma s_2(1-h_1)^2$$
$$+4s_1\bar{s}_2(1-h_0)(1-h_1)+2s_1^2\bar{s}_2(1-h_0)^2(1-h_1)+2s_1\Sigma s_2(1-h_0)(1-h_1)^2$$
$$+s_1^2\Sigma s_2(1-h_0)^2(1-h_1)^2+2cov(r_2,s_2)(1-h_1)-(1+R_1)^2(1+r_2)^2\Big)$$

$$E\Big(v[.]-v[(1+R_1)(1+\tilde{R}_2)]\Big)^2\approx$$
$$v'^2[0]\Big(s_1^2(1-h_0)^2+\Sigma s_2(1-h_1)^2+2s_1\bar{s}_2(1-h_0)(1-h_1)+2s_1^2\bar{s}_2(1-h_0)^2(1-h_1)$$
$$+2s_1\Sigma s_2(1-h_0)(1-h_1)^2+s_1^2\Sigma s_2(1-h_0)^2(1-h_1)^2\Big)$$

This gives us the expected regret function over s_2^-:

$$\begin{aligned}
&kE_{s_2^+}g\Big(v[(1+R_1+s_1(1-h_0))(1+\tilde{R}_2+\tilde{s}_2(1-h_1))]-v[(1+R_1)(1+\tilde{R}_2)]\Big)\approx\\
&kg\Big(0\Big)+kg'\Big(0\Big)v'[0]\Big(1+R_1+r_2+R_1r_2+s_1(1-h_0)+\bar{s}_2^-(1-h_1)\\
&+s_1\bar{s}_2^-(1-h_0)(1-h_1)-(1+R_1)(1+r_2)\Big)+\\
&\frac{1}{2}kg'\Big(0\Big)v''[0]\Big(1+2R_1+R_1^2+2r_2+\Sigma r_2+4R_1r_2+2R_1\Sigma r_2+2R_1^2r_2+R_1^2\Sigma r_2\\
&+2s_1(1-h_0)+2\bar{s}_2^-(1-h_1)+s_1^2(1-h_0)^2+\Sigma s_2^-(1-h_1)^2\\
&+4s_1\bar{s}_2^-(1-h_0)(1-h_1)+2s_1^2\bar{s}_2^-(1-h_0)^2(1-h_1)+2s_1\Sigma s_2^-(1-h_0)(1-h_1)^2\\
&+s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1)^2+2cov(r_2,s_2^-)(1-h_1)-(1+R_1)^2(1+r_2)^2\Big)+\\
&\frac{1}{2}kg''\Big(0\Big)v'^2[0]\Big(s_1^2(1-h_0)^2+\Sigma s_2^-(1-h_1)^2+2s_1\bar{s}_2^-(1-h_0)(1-h_1)\\
&+2s_1^2\bar{s}_2^-(1-h_0)^2(1-h_1)+2s_1\Sigma s_2^-(1-h_0)(1-h_1)^2+s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1)^2\Big).
\end{aligned} \tag{23}$$

For Case 1 the expected utility is the sum of equation (19), (20) and (21). Remember that $g\Big(0\Big) = 0$. Furthermore, we denote $v[0] = v$, $g\Big(0\Big) = g$, $v'[0] = v'$ and so on:

$$
\begin{aligned}
&Eu(.) \approx v + v'\Big(1 + R_1 + r_2 + R_1 r_2 + s_1(1-h_0) + \bar{s}_2(1-h_1) + s_1\bar{s}_2(1-h_0)(1-h_1)\Big) + \\
&\frac{1}{2}v''\Big(1 + 2R_1 + R_1^2 + 2r_2 + \Sigma r_2 + 4R_1 r_2 + 2R_1\Sigma r_2 + 2R_1^2 r_2 + R_1^2\Sigma r_2 \\
&+ 2s_1(1-h_0) + 2\bar{s}_2(1-h_1) + s_1^2(1-h_0)^2 + \Sigma s_2(1-h_1)^2 \\
&+ 4s_1\bar{s}_2(1-h_0)(1-h_1) + 2s_1^2\bar{s}_2(1-h_0)^2(1-h_1) + 2s_1\Sigma s_2(1-h_0)(1-h_1)^2 \\
&+ s_1^2\Sigma s_2(1-h_0)^2(1-h_1)^2 + 2cov(r_2, s_2)(1-h_1)\Big) \\
&kg + kg'v'\Big(1 + R_1 + r_2 + R_1 r_2 + s_1(1-h_0) + \bar{s}_2^+(1-h_1) + s_1\bar{s}_2^+(1-h_0)(1-h_1) \\
&- (1 + R_1 + s_1)(1 + r_2 + \bar{s}_2^+)\Big) + \\
&\frac{1}{2}kg'v''\Big(1 + 2R_1 + R_1^2 + 2r_2 + \Sigma r_2 + 4R_1 r_2 + 2R_1\Sigma r_2 + 2R_1^2 r_2 + R_1^2\Sigma r_2 \\
&+ 2s_1(1-h_0) + 2\bar{s}_2^+(1-h_1) + s_1^2(1-h_0)^2 + \Sigma s_2^+(1-h_1)^2 \\
&+ 4s_1\bar{s}_2^+(1-h_0)(1-h_1) + 2s_1^2\bar{s}_2^+(1-h_0)^2(1-h_1) + 2s_1\Sigma s_2^+(1-h_0)(1-h_1)^2 \\
&+ s_1^2\Sigma s_2^+(1-h_0)^2(1-h_1)^2 + 2cov(r_2, s_2^+)(1-h_1) - (1 + R_1 + s_1)^2(1 + r_2 + \bar{s}_2^+)^2\Big) + \\
&\frac{1}{2}kg''v'^2\Big(s_1^2h_0^2 + \Sigma s_2^+h_1^2 + 2s_1\bar{s}_2^+h_0h_1 - 2s_1^2\bar{s}_2^+(-h_0^2 - h_0h_1 + h_0^2h_1) \\
&- 2s_1\Sigma s_2^+(-h_0h_1 - h_1^2 + h_0h_1^2) + s_1^2\Sigma s_2^+(-h_0 - h_1 + h_0h_1)^2\Big) \\
&kg + kg'v'\Big(1 + R_1 + r_2 + R_1 r_2 + s_1(1-h_0) + \bar{s}_2^-(1-h_1) + s_1\bar{s}_2^-(1-h_0)(1-h_1) \\
&- (1 + R_1 + s_1)(1 + r_2)\Big) + \\
&\frac{1}{2}kg'v''\Big(1 + 2R_1 + R_1^2 + 2r_2 + \Sigma r_2 + 4R_1 r_2 + 2R_1\Sigma r_2 + 2R_1^2 r_2 + R_1^2\Sigma r_2 \\
&+ 2s_1(1-h_0) + 2\bar{s}_2^-(1-h_1) + s_1^2(1-h_0)^2 + \Sigma s_2^-(1-h_1)^2 \\
&+ 4s_1\bar{s}_2^-(1-h_0)(1-h_1) + 2s_1^2\bar{s}_2^-(1-h_0)^2(1-h_1) + 2s_1\Sigma s_2^-(1-h_0)(1-h_1)^2 \\
&+ s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1)^2 + 2cov(r_2, s_2^-)(1-h_1) - (1 + R_1 + s_1)^2(1 + r_2)^2\Big) + \\
&\frac{1}{2}kg''v'^2\Big(s_1^2h_0^2 + \Sigma s_2^-(1-h_1)^2 - 2s_1\bar{s}_2^-h_0(1-h_1) - 2s_1^2\bar{s}_2^-h_0(1-h_0)(1-h_1) \\
&+ 2s_1\Sigma s_2^-(1-h_0)(1-h_1)^2 + s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1)^2\Big).
\end{aligned}
$$

We take the first derivative with respect to h_1 to get the optimal hedge ratio in t_1 and set it equal to zero:

$$
\begin{aligned}
\frac{\partial Eu(.)}{\partial h_1} =& v'\Big(- \bar{s}_2 - s_1\bar{s}_2(1-h_0)\Big)+ \\
& kg'v'\Big(- \bar{s}_2^+ - s_1\bar{s}_2^+(1-h_0)\Big)+ \\
& kg'v'\Big(- \bar{s}_2^- - s_1\bar{s}_2^-(1-h_0)\Big)+ \\
& v''\Big(- \bar{s}_2 - \Sigma s_2(1-h_1) - 2s_1\bar{s}_2(1-h_0) - s_1^2\bar{s}_2(1-h_0)^2 \\
& - 2s_1\Sigma s_2(1-h_0)(1-h_1) - s_1^2\Sigma s_2(1-h_0)^2(1-h_1) - cov(r_2,s_2)\Big)+ \\
& kg'v''\Big(- \bar{s}_2^+ - \Sigma s_2^+(1-h_1) - 2s_1\bar{s}_2^+(1-h_0) - s_1^2\bar{s}_2^+(1-h_0)^2 \\
& - 2s_1\Sigma s_2^+(1-h_0)(1-h_1) - s_1^2\Sigma s_2^+(1-h_0)^2(1-h_1) - cov(r_2,s_2^+)\Big)+ \\
& kg'v''\Big(- \bar{s}_2^- - \Sigma s_2^-(1-h_1) - 2s_1\bar{s}_2^-(1-h_0) - s_1^2\bar{s}_2^-(1-h_0)^2 \\
& - 2s_1\Sigma s_2^-(1-h_0)(1-h_1) - s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1) - cov(r_2,s_2^-)\Big)+ \\
& kg''v'^2\Big(\Sigma s_2^+ h_1 + s_1\bar{s}_2^+ h_0 + s_1^2\bar{s}_2^+(1-h_0)h_0 - s_1\Sigma s_2^+(-h_0 - 2h_1 + 2h_0h_1) \\
& - s_1^2\Sigma s_2^+(-h_0 - h_1 + h_0^2 + 2h_0h_1 - h_0^2h_1)\Big)+ \\
& kg''v'^2\Big(- \Sigma s_2^-(1-h_1) + s_1\bar{s}_2^- h_0 + s_1^2\bar{s}_2^-(1-h_0)h_0 - 2s_1\Sigma s_2^-(1-h_0)(1-h_1) \\
& - s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1)\Big). \\
& = 0
\end{aligned}
$$

We can simplify, using: $\bar{s}_2^+ + \bar{s}_2^- = \bar{s}_2$; $\Sigma_{s_2}^+ + \Sigma_{s_2}^- = \Sigma_{s_2}$

$$
\begin{aligned}
& \Big(v' + kg'v'\Big)\Big(- \bar{s}_2 - s_1\bar{s}_2(1-h_0)\Big)+ \\
& \Big(v'' + kg'v''\Big)\Big(- \bar{s}_2 - \Sigma s_2(1-h_1) - 2s_1\bar{s}_2(1-h_0) - s_1^2\bar{s}_2(1-h_0)^2 \\
& - 2s_1\Sigma s_2(1-h_0)(1-h_1) - s_1^2\Sigma s_2(1-h_0)^2(1-h_1) - cov(r_2,s_2)\Big)+ \\
kg''v'^2\Big(& - \Sigma s_2^+(1-h_1) + \Sigma s_2^+ + s_1\bar{s}_2^+ h_0 + s_1^2\bar{s}_2^+(1-h_0)h_0 - 2s_1\Sigma s_2^+(1-h_0)(1-h_1) \\
& + s_1\Sigma s_2^+(2-h_0) - s_1^2\Sigma s_2^+(1-h_0)^2(1-h_1) + s_1^2\Sigma s_2^+(1-h_0)\Big)+ \\
kg''v'^2\Big(& - \Sigma s_2^-(1-h_1) + s_1\bar{s}_2^- h_0 + s_1^2\bar{s}_2^-(1-h_0)h_0 - 2s_1\Sigma s_2^-(1-h_0)(1-h_1) \\
& - s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1)\Big) \\
& = 0.
\end{aligned}
$$

Hence:

$$
\begin{aligned}
&\Big(v' + kg'v'\Big)\Big(- \bar{s}_2 - s_1\bar{s}_2(1-h_0)\Big) + \\
&\Big(v'' + kg'v''\Big)\Big(- \bar{s}_2 - \Sigma s_2(1-h_1) - 2s_1\bar{s}_2(1-h_0) - s_1^2\bar{s}_2(1-h_0)^2 \\
&- 2s_1\Sigma s_2(1-h_0)(1-h_1) - s_1^2\Sigma s_2(1-h_0)^2(1-h_1) - cov(r_2,s_2)\Big) + \\
kg''v'^2&\Big(- \Sigma s_2(1-h_1) + s_1\bar{s}_2h_0 + s_1^2\bar{s}_2(1-h_0)h_0 - 2s_1\Sigma s_2(1-h_0)(1-h_1) \\
&- s_1^2\Sigma s_2(1-h_0)^2(1-h_1)\Big) + \\
kg''v'^2&\Big(\Sigma s_2^+ + s_1\Sigma s_2^+(2-h_0) + s_1^2\Sigma s_2^+(1-h_0)\Big) \\
&= 0.
\end{aligned}
$$

Therefore:

$$
\begin{aligned}
&\Big(v' + kg'v'\Big)\Big(- \bar{s}_2 - s_1\bar{s}_2(1-h_0)\Big) + \\
&\Big(v'' + kg'v''\Big)\Big(- \bar{s}_2 - 2s_1\bar{s}_2(1-h_0) - s_1^2\bar{s}_2(1-h_0)^2 - cov(r_2,s_2)\Big) + \\
&kg''v'^2\Big(s_1\bar{s}_2h_0 + s_1^2\bar{s}_2(1-h_0)h_0\Big) + \\
&kg''v'^2\Big(\Sigma s_2^+ + s_1\Sigma s_2^+(2-h_0) + s_1^2\Sigma s_2^+(1-h_0)\Big) \\
&= \\
&\Big(v'' + kg'v'' + kg''v'^2\Big)\Big(\Sigma s_2 + 2s_1\Sigma s_2(1-h_0) + s_1^2\Sigma s_2(1-h_0)^2\Big)(1-h_1).
\end{aligned}
$$

Using the traditional definition of risk aversion $\lambda = \frac{-v''}{v'}$ and the definition of regret aversion according Bell (1983), adding the risk aversion weighting factor k, $\rho = \frac{-kg''v'}{1+kg'}$, we get: $\frac{1}{\rho+\lambda} = \frac{v'+kg'v'}{-v''-kg'v''-kg''v'^2}$, $\frac{\lambda}{\rho+\lambda} = \frac{v''+kg'v''}{v''kg'v''kg''v'^2}$ and $\frac{\rho}{\rho+\lambda} = \frac{kg''v'^2}{v''+kg'v''+kg''v'^2}$

$$
\begin{aligned}
h_1^* = 1 &- \frac{1}{\rho+\lambda}\frac{\bar{s}_2 + s_1\bar{s}_2(1-h_0)}{\Sigma s_2 + 2s_1\Sigma s_2(1-h_0) + s_1^2\Sigma s_2(1-h_0)^2} \\
&+ \frac{\lambda}{\rho+\lambda}\frac{\bar{s}_2 + 2s_1\bar{s}_2(1-h_0) + s_1^2\bar{s}_2(1-h_0)^2 + cov(r_2,s_2)}{\Sigma s_2 + 2s_1\Sigma s_2(1-h_0) + s_1^2\Sigma s_2(1-h_0)^2} \\
&- \frac{\rho}{\rho+\lambda}\frac{s_1\bar{s}_2h_0 + s_1^2\bar{s}_2(1-h_0)h_0}{\Sigma s_2 + 2s_1\Sigma s_2(1-h_0) + s_1^2\Sigma s_2(1-h_0)^2} \\
&- \frac{\rho}{\rho+\lambda}\frac{\Sigma s_2^+ + s_1\Sigma s_2^+(2-h_0) + s_1^2\Sigma s_2^+(1-h_0)}{\Sigma s_2 + 2s_1\Sigma s_2(1-h_0) + s_1^2\Sigma s_2(1-h_0)^2}.
\end{aligned}
$$

For Case 1 we get the optimal h_1^* for s_1^+:

$$\begin{aligned}h_1^* = 1 &- \frac{1}{\rho+\lambda}\frac{\bar{s}_2}{\Sigma s_2(1+s_1(1-h_0))} + \frac{\lambda}{\rho+\lambda}\Big(\frac{\bar{s}_2}{\Sigma s_2} + \frac{cov(r_2,s_2)}{\Sigma s_2(1+s_1(1-h_0))^2}\Big) \\ &- \frac{\rho}{\rho+\lambda}\frac{s_1\bar{s}_2h_0}{\Sigma s_2(1+s_1(1-h_0))} - \frac{\rho}{\rho+\lambda}\frac{\Sigma s_2^+(1+s_1)}{\Sigma s_2(1+s_1(1-h_0))}.\end{aligned} \tag{24}$$

Further simplification gives us:

$$\begin{aligned}h_1^* = 1 &- \frac{1}{\rho+\lambda}\frac{\bar{s}_2}{\Sigma s_2}\Big(\frac{1}{1+s_1(1-h_0)} - \lambda\Big) + \frac{\lambda}{\rho+\lambda}\frac{cov(r_2,s_2)}{\Sigma s_2(1+s_1(1-h_0))^2} \\ &- \frac{\rho}{\rho+\lambda}\frac{\Sigma s_2^+(1+s_1)+s_1\bar{s}_2h_0}{\Sigma s_2(1+s_1(1-h_0))}.\end{aligned}$$

Let's assume that $\bar{s}_2 = 0$. Then $\Sigma_{s_2}^+ = \Sigma_{s_2}^- = \frac{1}{2}\Sigma_{s_2}$; and also $cov(r_2,s_2) = 0$, which corresponds to the case with $R_1 = R_2 = 0$ in the first place:

$$h_1^* = 1 - \frac{1}{2}\frac{\rho}{\rho+\lambda}\frac{1+s_1}{1+s_1(1-h_0)}. \tag{25}$$

Let us also assume that the hedge ratio of Period 1, h_0, was equal to 0:

$$h_1^* = 1 - \frac{1}{2}\frac{\rho}{\rho+\lambda}.$$

If we only assume h_0 to be equal to 0:

$$h_1^* = 1 - \frac{1}{\rho+\lambda}\frac{\bar{s}_2}{\Sigma s_2}\Big(\frac{1}{1+s_1} - \lambda\Big) + \frac{\lambda}{\rho+\lambda}\frac{cov(r_2,s_2)}{\Sigma s_2(1+s_1)^2} - \frac{\rho}{\rho+\lambda}\frac{\Sigma s_2^+}{\Sigma s_2}.$$

For Case 2 the expected utility is the sum of equation (19), (22) and (23):

$$
\begin{aligned}
&Eu(.) \approx v + v'\Big(1 + R_1 + r_2 + R_1 r_2 + s_1(1-h_0) + \bar{s}_2(1-h_1) + s_1\bar{s}_2(1-h_0)(1-h_1)\Big) + \\
&\frac{1}{2}v''\Big(1 + 2R_1 + R_1^2 + 2r_2 + \Sigma r_2 + 4R_1 r_2 + 2R_1\Sigma r_2 + 2R_1^2 r_2 + R_1^2\Sigma r_2 \\
&+ 2s_1(1-h_0) + 2\bar{s}_2(1-h_1) + s_1^2(1-h_0)^2 + \Sigma s_2(1-h_1)^2 \\
&+ 4s_1\bar{s}_2(1-h_0)(1-h_1) + 2s_1^2\bar{s}_2(1-h_0)^2(1-h_1) + 2s_1\Sigma s_2(1-h_0)(1-h_1)^2 \\
&+ s_1^2\Sigma s_2(1-h_0)^2(1-h_1)^2 + 2cov(r_2, s_2)(1-h_1)\Big) \\
&kg + kg'v'\Big(1 + R_1 + r_2 + R_1 r_2 + s_1(1-h_0) + \bar{s}_2^+(1-h_1) + s_1\bar{s}_2^+(1-h_0)(1-h_1) \\
&- (1+R_1)(1 + r_2 + \bar{s}_2^+)\Big) \\
&\frac{1}{2}kg'v''\Big(1 + 2R_1 + R_1^2 + 2r_2 + \Sigma r_2 + 4R_1 r_2 + 2R_1\Sigma r_2 + 2R_1^2 r_2 + R_1^2\Sigma r_2 \\
&+ 2s_1(1-h_0) + 2\bar{s}_2^+(1-h_1) + s_1^2(1-h_0)^2 + \Sigma s_2^+(1-h_1)^2 \\
&+ 4s_1\bar{s}_2^+(1-h_0)(1-h_1) + 2s_1^2\bar{s}_2^+(1-h_0)^2(1-h_1) + 2s_1\Sigma s_2^+(1-h_0)(1-h_1)^2 \\
&+ s_1^2\Sigma s_2^+(1-h_0)^2(1-h_1)^2 + 2cov(r_2, s_2^+)(1-h_1) - (1+R_1)^2(1 + r_2 + \bar{s}_2^+)^2\Big) + \\
&\frac{1}{2}kg''v'^2\Big(s_1^2(1-h_0)^2 + \Sigma s_2^+ h_1^2 - 2s_1\bar{s}_2^+(1-h_0)h_1 + 2s_1^2\bar{s}_2^+(1-h_0)^2(1-h_1) \\
&- 2s_1\Sigma s_2^+(1-h_0)(1-h_1)h_1 + s_1^2\Sigma s_2^+(1-h_0)^2(1-h_1)^2\Big) \\
&kg + kg'v'\Big(1 + R_1 + r_2 + R_1 r_2 + s_1(1-h_0) + \bar{s}_2^-(1-h_1) + s_1\bar{s}_2^-(1-h_0)(1-h_1) \\
&- (1+R_1)(1+r_2)\Big) + \\
&\frac{1}{2}kg'v''\Big(1 + 2R_1 + R_1^2 + 2r_2 + \Sigma r_2 + 4R_1 r_2 + 2R_1\Sigma r_2 + 2R_1^2 r_2 + R_1^2\Sigma r_2 \\
&+ 2s_1(1-h_0) + 2\bar{s}_2^-(1-h_1) + s_1^2(1-h_0)^2 + \Sigma s_2^-(1-h_1)^2 \\
&+ 4s_1\bar{s}_2^-(1-h_0)(1-h_1) + 2s_1^2\bar{s}_2^-(1-h_0)^2(1-h_1) + 2s_1\Sigma s_2^-(1-h_0)(1-h_1)^2 \\
&+ s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1)^2 + 2cov(r_2, s_2^-)(1-h_1) - (1+R_1)^2(1+r_2)^2\Big) + \\
&\frac{1}{2}kg''v'^2\Big(s_1^2(1-h_0)^2 + \Sigma s_2^-(1-h_1)^2 + 2s_1\bar{s}_2^-(1-h_0)(1-h_1) \\
&+ 2s_1^2\bar{s}_2^-(1-h_0)^2(1-h_1) + 2s_1\Sigma s_2^-(1-h_0)(1-h_1)^2 + s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1)^2\Big).
\end{aligned}
$$

We take the first derivative with respect to h_1 to get the optimal hedge ratio in t_1 and set it equal to zero:

$$\begin{aligned}
\frac{\partial Eu(.)}{\partial h_1} =& v'\Big(- \bar{s}_2 - s_1\bar{s}_2(1-h_0)\Big)+ \\
& kg'v'\Big(- \bar{s}_2^+ - s_1\bar{s}_2^+(1-h_0)\Big)+ \\
& kg'v'\Big(- \bar{s}_2^- - s_1\bar{s}_2^-(1-h_0)\Big)+ \\
& v''\Big(- \bar{s}_2 - \Sigma s_2(1-h_1) - 2s_1\bar{s}_2(1-h_0) - s_1^2\bar{s}_2(1-h_0)^2 \\
& - 2s_1\Sigma s_2(1-h_0)(1-h_1) - s_1^2\Sigma s_2(1-h_0)^2(1-h_1) - cov(r_2, s_2)\Big)+ \\
& kg'v''\Big(- \bar{s}_2^+ - \Sigma s_2^+(1-h_1) - 2s_1\bar{s}_2^+(1-h_0) - s_1^2\bar{s}_2^+(1-h_0)^2 \\
& - 2s_1\Sigma s_2^+(1-h_0)(1-h_1) - s_1^2\Sigma s_2^+(1-h_0)^2(1-h_1) - cov(r_2, s_2^+)\Big)+ \\
& kg'v''\Big(- \bar{s}_2^- - \Sigma s_2^-(1-h_1) - 2s_1\bar{s}_2^-(1-h_0) - s_1^2\bar{s}_2^-(1-h_0)^2 \\
& - 2s_1\Sigma s_2^-(1-h_0)(1-h_1) - s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1) - cov(r_2, s_2^-)\Big)+ \\
& kg''v'^2\Big(\Sigma s_2^+ h_1 - s_1\bar{s}_2^+(1-h_0) - s_1^2\bar{s}_2^+(1-h_0)^2 - s_1\Sigma s_2^+(1-h_0)(1-2h_1) \\
& - s_1^2\Sigma s_2^+(1-h_0)^2(1-h_1)\Big)+ \\
& kg''v'^2\Big(- \Sigma s_2^-(1-h_1) - s_1\bar{s}_2^-(1-h_0) - s_1^2\bar{s}_2^-(1-h_0)^2 - 2s_1\Sigma s_2^-(1-h_0)(1-h_1) \\
& - s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1)\Big) \\
& = 0.
\end{aligned}$$

We can simplify, using: $\bar{s}_2^+ + \bar{s}_2^- = \bar{s}_2$; $\Sigma_{s_2}^+ + \Sigma_{s_2}^- = \Sigma_{s_2}$

$$\begin{aligned}
& \Big(v' + kg'v'\Big)\Big(- \bar{s}_2 - s_1\bar{s}_2(1-h_0)\Big)+ \\
& \Big(v'' + kg'v''\Big)\Big(- \bar{s}_2 - \Sigma s_2(1-h_1) - 2s_1\bar{s}_2(1-h_0) - s_1^2\bar{s}_2(1-h_0)^2 \\
& - 2s_1\Sigma s_2(1-h_0)(1-h_1) - s_1^2\Sigma s_2(1-h_0)^2(1-h_1) - cov(r_2, s_2)\Big)+ \\
& kg''v'^2\Big(- \Sigma s_2^+(1-h_1) + \Sigma s_2^+ - s_1\bar{s}_2^+(1-h_0) - s_1^2\bar{s}_2^+(1-h_0)^2 - 2s_1\Sigma s_2^+(1-h_0)(1-h_1) \\
& + s_1\Sigma s_2^+(1-h_0) - s_1^2\Sigma s_2^+(1-h_0)^2(1-h_1)\Big)+ \\
& kg''v'^2\Big(- \Sigma s_2^-(1-h_1) - s_1\bar{s}_2^-(1-h_0) - s_1^2\bar{s}_2^-(1-h_0)^2 - 2s_1\Sigma s_2^-(1-h_0)(1-h_1) \\
& - s_1^2\Sigma s_2^-(1-h_0)^2(1-h_1)\Big) \\
& = 0.
\end{aligned}$$

Hence:

$$
\begin{aligned}
&\Big(v' + kg'v'\Big)\Big(- \bar{s}_2 - s_1\bar{s}_2(1-h_0)\Big) + \\
&\Big(v'' + kg'v''\Big)\Big(- \bar{s}_2 - \Sigma s_2(1-h_1) - 2s_1\bar{s}_2(1-h_0) - s_1^2\bar{s}_2(1-h_0)^2 \\
&- 2s_1\Sigma s_2(1-h_0)(1-h_1) - s_1^2\Sigma s_2(1-h_0)^2(1-h_1) - cov(r_2,s_2)\Big) + \\
&kg''v'^2\Big(- \Sigma s_2(1-h_1) - s_1\bar{s}_2(1-h_0) - s_1^2\bar{s}_2(1-h_0)^2 - 2s_1\Sigma s_2(1-h_0)(1-h_1) \\
&- s_1^2\Sigma s_2^+(1-h_0)^2(1-h_1)\Big) + \\
&kg''v'^2\Big(\Sigma s_2^+ + s_1\Sigma s_2^+(1-h_0)\Big). \\
&= 0
\end{aligned}
$$

Therefore:

$$
\begin{aligned}
&\Big(v' + kg'v'\Big)\Big(- \bar{s}_2 - s_1\bar{s}_2(1-h_0)\Big) + \\
&\Big(v'' + kg'v''\Big)\Big(- \bar{s}_2 - 2s_1\bar{s}_2(1-h_0) - s_1^2\bar{s}_2(1-h_0)^2 - cov(r_2,s_2)\Big) + \\
&kg''v'^2\Big(- s_1\bar{s}_2(1-h_0) - s_1^2\bar{s}_2(1-h_0)^2\Big) + \\
&kg''v'^2\Big(\Sigma s_2^+ + s_1\Sigma s_2^+(1-h_0)\Big) \\
&= \\
&\Big(v'' + kg'v'' + kg''v'^2\Big)\Big(\Sigma s_2 + 2s_1\Sigma s_2(1-h_0) + s_1^2\Sigma s_2(1-h_0)^2\Big)(1-h_1).
\end{aligned}
$$

Using the definition of risk and regret aversion:

$$
\begin{aligned}
h_1^* = 1 &- \frac{1}{\rho+\lambda}\frac{\bar{s}_2 + s_1\bar{s}_2(1-h_0)}{\Sigma s_2 + 2s_1\Sigma s_2(1-h_0) + s_1^2\Sigma s_2(1-h_0)^2} \\
&+ \frac{\lambda}{\rho+\lambda}\frac{\bar{s}_2 + 2s_1\bar{s}_2(1-h_0) + s_1^2\bar{s}_2(1-h_0)^2 + cov(r_2,s_2)}{\Sigma s_2 + 2s_1\Sigma s_2(1-h_0) + s_1^2\Sigma s_2(1-h_0)^2} \\
&+ \frac{\rho}{\rho+\lambda}\frac{s_1\bar{s}_2(1-h_0) + s_1^2\bar{s}_2(1-h_0)^2}{\Sigma s_2 + 2s_1\Sigma s_2(1-h_0) + s_1^2\Sigma s_2(1-h_0)^2} \\
&- \frac{\rho}{\rho+\lambda}\frac{\Sigma s_2^+ + s_1\Sigma s_2^+(1-h_0)}{\Sigma s_2 + 2s_1\Sigma s_2(1-h_0) + s_1^2\Sigma s_2(1-h_0)^2}.
\end{aligned}
$$

For Case 2 we get the optimal h_1^* for s_1^-:

$$
\begin{aligned}
h_1^* = 1 &- \frac{1}{\rho+\lambda}\frac{\bar{s}_2}{\Sigma s_2(1+s_1(1-h_0))} + \frac{\lambda}{\rho+\lambda}\Big(\frac{\bar{s}_2}{\Sigma s_2} + \frac{cov(r_2,s_2)}{\Sigma s_2(1+s_1(1-h_0))^2}\Big) \\
&+ \frac{\rho}{\rho+\lambda}\frac{s_1\bar{s}_2(1-h_0)}{\Sigma s_2(1+s_1(1-h_0))} - \frac{\rho}{\rho+\lambda}\frac{\Sigma s_2^+}{\Sigma s_2(1+s_1(1-h_0))}.
\end{aligned}
\tag{26}
$$

Further simplification gives us:

$$h_1^* = 1 - \frac{1}{\rho+\lambda}\frac{\bar{s}_2}{\Sigma s_2}\Big(\frac{1}{1+s_1(1-h_0)} - \lambda\Big) + \frac{\lambda}{\rho+\lambda}\frac{cov(r_2,s_2)}{\Sigma s_2(1+s_1(1-h_0))^2}$$
$$-\frac{\rho}{\rho+\lambda}\frac{\Sigma s_2^+ - s_1\bar{s}_2(1-h_0)}{\Sigma s_2(1+s_1(1-h_0))}.$$

Let's assume that $\bar{s}_2 = 0$. Then $\Sigma_{s_2}^+ = \Sigma_{s_2}^- = \frac{1}{2}\Sigma_{s_2}$; and also $cov(r_2, s_2) = 0$, which corresponds to the case with $R_1 = R_2 = 0$ in the first place:

$$h_1^* = 1 - \frac{1}{2}\frac{\rho}{\rho+\lambda}\frac{1}{1+s_1(1-h_0)}. \tag{27}$$

Let us also assume that the hedge ratio of period 1, h_0 was equal to 1:

$$h_1^* = 1 - \frac{1}{2}\frac{\rho}{\rho+\lambda}.$$

If we only assume h_0 to be equal to 1:

$$h_1^* = 1 - \frac{1}{\rho+\lambda}\frac{\bar{s}_2}{\Sigma s_2}\Big(1-\lambda\Big) + \frac{\lambda}{\rho+\lambda}\frac{cov(r_2,s_2)}{\Sigma s_2} - \frac{\rho}{\rho+\lambda}\frac{\Sigma s_2^+}{\Sigma s_2}.$$

Appendix C Derivatives of Proposition 2 with respect to the model variables

The derivatives of Proposition 2 with respect to s_1 are given by:

$$s_1^+ : \frac{1}{\rho+\lambda}\frac{1}{\Sigma s_2}\left(\frac{-(\Sigma_{s_2}^+ + \bar{s}_2)h_0\rho + \bar{s}_2(1-h_0)}{(1+s_1(1-h_0))^2} - \frac{2\lambda cov(r_2,s_2)(1-h_0)}{(1+s_1(1-h_0))^3}\right) \text{ and}$$
$$s_1^- : \frac{1}{\rho+\lambda}\frac{1-h_0}{\Sigma s_2}\left(\frac{(\Sigma_{s_2}^+ + \bar{s}_2)\rho + \bar{s}_2}{(1+s_1(1-h_0))^2} - \frac{2\lambda cov(r_2,s_2)}{(1+s_1(1-h_0))^3}\right).$$

The derivatives of Proposition 2 with respect to s_1 are given by:[24]

$$s_1^+ : \frac{1}{\rho+\lambda}\frac{s_1}{\Sigma s_2}\left(\frac{-(\Sigma_{s_2}^+ + \bar{s}_2)\rho(1+s_1) - \bar{s}_2}{(1+s_1(1-h_0))^2} + \frac{2\lambda cov(r_2,s_2)}{(1+s_1(1-h_0))^3}\right) \text{ and}$$
$$s_1^- : \frac{1}{\rho+\lambda}\frac{-s_1}{\Sigma s_2}\left(\frac{(\Sigma_{s_2}^+ + \bar{s}_2)\rho + \bar{s}_2}{(1+s_1(1-h_0))^2} - \frac{2\lambda cov(r_2,s_2)}{(1+s_1(1-h_0))^3}\right).$$

The derivatives of Proposition 2 with respect to λ are given by:

$$s_1^+ : \frac{1}{(\rho+\lambda)^2}\frac{1}{\Sigma s_2}\left(\rho\left[\frac{\Sigma_{s_2}^+(1+s_1) + s_1\bar{s}_2h_0}{1+s_1(1-h_0)} + \bar{s}_2 + \frac{cov(r_2,s_2)}{(1+s_1(1-h_0))^2}\right] + \frac{\bar{s}_2}{1+s_1(1-h_0)}\right) \text{ and}$$
$$s_1^- : \frac{1}{(\rho+\lambda)^2}\frac{1}{\Sigma s_2}\left(\rho\left[\frac{\Sigma_{s_2}^+(1+s_1) - s_1\bar{s}_2h_0}{1+s_1(1-h_0)} + \bar{s}_2 + \frac{cov(r_2,s_2)}{(1+s_1(1-h_0))^2}\right] + \frac{\bar{s}_2}{1+s_1(1-h_0)}\right).$$

The derivatives of Proposition 2 with respect to ρ are given by:

$$s_1^+ : -\frac{1}{(\rho+\lambda)^2}\frac{1}{\Sigma s_2}\left(\lambda\left[\frac{\Sigma_{s_2}^+(1+s_1) + s_1\bar{s}_2h_0}{1+s_1(1-h_0)} + \bar{s}_2 + \frac{cov(r_2,s_2)}{(1+s_1(1-h_0))^2}\right] - \frac{\bar{s}_2}{1+s_1(1-h_0)}\right) \text{ and}$$
$$s_1^- : -\frac{1}{(\rho+\lambda)^2}\frac{1}{\Sigma s_2}\left(\lambda\left[\frac{\Sigma_{s_2}^+(1+s_1) - s_1\bar{s}_2h_0}{1+s_1(1-h_0)} + \bar{s}_2 + \frac{cov(r_2,s_2)}{(1+s_1(1-h_0))^2}\right] - \frac{\bar{s}_2}{1+s_1(1-h_0)}\right).$$

The derivatives of Proposition 2 with respect to $\bar{s}_2$ are given by:

$$s_1^+ : -\frac{1}{\rho+\lambda}\frac{\bar{s}_2}{\Sigma s_2}\left(\frac{1+\rho s_1h_0}{1+s_1(1-h_0)} - \lambda\right) \text{ and } s_1^- : -\frac{1}{\rho+\lambda}\frac{\bar{s}_2}{\Sigma s_2}\left(\frac{1+\rho s_1(1-h_0)}{1+s_1(1-h_0)} - \lambda\right).$$

Appendix D Non-parametric exposure estimation

[Table D.1 about here.]

[24] Recall that s_1^- is negative.

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Tables

Table 1: Summary statistics of yearly exchange rate exposures

Year	Comp.	γ_i	if neg.	if pos.	**SN***	$\bar{R}^2$
1995	879	**-0.169**	-1.02	0.93	**12.7%**	15.0%
1996	959	**0.084**	-2.23	2.22	**11.7%**	17.8%
1997	1,044	**0.115**	-1.48	1.48	**12.1%**	18.7%
1998	1,112	**-0.067**	-0.86	0.91	**13.9%**	29.4%
1999	1,169	**0.129**	-1.86	1.86	**13.4%**	16.7%
2000	1,262	**0.676**	-1.74	2.49	**10.9%**	22.5%
2001	1,325	**0.221**	-1.61	1.89	**11.3%**	33.8%
2002	1,353	**-0.367**	-2.40	1.73	**23.1%**	23.9%
2003	1,376	**-0.076**	-1.51	1.31	**13.7%**	25.1%
2004	1,410	**-0.045**	-1.09	1.12	**12.6%**	25.8%
2005	1,465	**-0.041**	-1.17	1.16	**15.5%**	28.0%
2006	1,525	**-0.258**	-1.43	1.27	**14.0%**	28.1%
2007	1,596	**-0.419**	-1.76	1.66	**16.9%**	28.2%
2008	1,669	**-0.409**	-1.47	0.93	**23.7%**	43.4%
2009	1,687	**-0.204**	-1.89	1.47	**16.6%**	34.9%
2010	1,735	**-0.176**	-1.28	1.02	**13.0%**	36.2%
2011	1,790	**-0.060**	-1.10	0.96	**15.4%**	42.2%
2012	1,851	**-0.051**	-1.57	1.56	**12.7%**	26.4%
2013	1,916	**-0.003**	-1.17	1.08	**12.5%**	23.3%
2014	2,016	**-0.067**	-1.60	1.63	**12.1%**	27.4%
2015	2,080	**-0.160**	-1.08	1.00	**12.9%**	27.0%
avg.	1,487	**-0.064**	-1.49	1.41	**14.3%**	27.3%

This table shows the results of a time series regression for each company per year, whereby the number of lags is obtained from an autocorrelation test. γ_i is the average yearly exchange rate exposure. γ_i is also displayed for positive and negative values. The percentage amount of significant exchange rate sensitivities is given by SN. Significance level: * p<10%.

Table 2: Expected signs of model-derived variables

	All	Exporter		Importer		Proxies
	$\lvert\hat{\gamma}_{i,j}\rvert$	s_1^+	s_1^-	s_1^+	s_1^-	
Model-derived variables and expected signs:						
H1: s_1	$\circ$	+	-	+	-	Past exchange rate returns
H2: $\hat{\gamma}_{i,j-1}$	$\circ$	-	+	-	+	Past (lagged) yearly exposures
H3: λ	-	-	-	+	+	Discretionary accruals; executive characteristics; relative risk aversion parameter of Brenner (2015)
H4: ρ	+	+	+	-	-	Past gains and losses from derivative usage relative to exposure
H5: $\bar{s}_2$	$\circ$	+	+	+	+	Expected exchange rate (ARIMA)
H7:$\Sigma s_2^+/\Sigma s_2$	+	+	+	-	-	Skewness of squared values of expected exchange rate returns

The displayed signs of an exporter stems from our model analysis in Section 3 and is either positive or negative. We can apply our results to an importer by considering the inverted effect of the exchange rate. To analyze the effect on all companies (exporting as well as importing) we use the absolute values of $\hat{\gamma}_{i,j}$. Therefore we display the expected effect of the model variables on $\hat{\gamma}_{i,j}$ for higher divinations from zero. A $\circ$ is used if the combined effect of all companies is expected to be inconclusive and the sign of the effect has to be empirically evaluated. Note that for Hypothesis 2 we use $\hat{\gamma}_{i,j-1}$ for h_0 and thus display H2: h_0 as H2: $\hat{\gamma}_{i,j-1}$.

Table 3: Fixed-effects results of model hypotheses

	All	Exporter		Importer	
	$\lvert\hat{\gamma}_{i,j}\rvert$	s_1^+	s_1^-	s_1^+	s_1^-
Model-derived variables:					
H1: s_1	0.788***	2.677***	1.885*	-2.220***	-0.292
	(3.454)	(6.743)	(1.841)	(-5.600)	(-0.249)
H3: λ	-0.203***	-0.376***	-0.222	0.115	0.099
	(-3.621)	(-3.389)	(-1.271)	(1.327)	(0.669)
H5: $\bar{s}_2$	6.101***	9.961***	7.582***	-3.906***	-9.908***
	(14.925)	(12.607)	(8.043)	(-5.693)	(-9.022)
H7: $\Sigma s_2^+/\Sigma s_2$	0.140***	0.661***	-0.087*	-0.468***	0.058
	(7.919)	(20.167)	(-1.920)	(-14.824)	(1.029)
Controls:					
Size	-0.234***	-0.236***	-0.236***	0.275***	0.294***
	(-13.869)	(-8.420)	(-4.000)	(10.222)	(5.343)
Foreign Sales	-0.015	-0.142	-0.457	-0.177	0.228
	(-0.163)	(-0.866)	(-1.585)	(-1.147)	(0.776)
Intern. Inc.	0.021	-0.067	-0.022	0.113	-0.012
	(0.464)	(-0.749)	(-0.164)	(1.402)	(-0.101)
Leverage	0.005*	0.015**	-0.002	0.002	-0.019
	(1.653)	(2.000)	(-0.381)	(0.779)	(-1.522)
Quick Ratio	-0.002	0.011	-0.020*	0.004	0.012
	(-0.335)	(0.837)	(-1.888)	(0.652)	(0.973)
Div. p. E.	-0.417***	-0.353***	-0.102	0.355***	0.781***
	(-7.052)	(-3.013)	(-0.636)	(3.556)	(3.928)
R&D Sales	-0.001	-0.008	-0.016	-0.019	-0.008
	(-0.253)	(-1.003)	(-1.531)	(-1.585)	(-0.822)
Observations	24,259	7,171	4,657	7,221	5,210
R^2	0.115	0.156	0.121	0.107	0.133

Dependent variables: foreign exchange rate exposure as proxy for the current hedge ratio. 0.5% of the estimated exposures are winsorized on each end to account for outliners. Absolute values of the exposures are used for the first regression with all observations. For the latter, the sign of the exposure is used to separate the sample into exporters (EX) and importers (IM). For the last four regressions the past exchange rate return is also used to subdivide the sample. All regressions are estimated using a fixed-effects panel regression with robust and clustered standard errors on the company level. T-statistics are given in parentheses. The coefficients are tagged with the respective significance levels: * p<10%, ** p<5%, *** p<1%.

Table 4: Linear dynamic panel results of the model hypotheses

	All	Exporter		Importer	
	$\lvert\hat{\gamma}_{i,j}\rvert$	s_1^+	s_1^-	s_1^+	s_1^-
Model-derived variables and expected signs:					
H1: s_1	0.089	6.090***	-9.927***	-5.393***	9.465***
	(0.315)	(16.644)	(-16.559)	(-15.135)	(13.717)
H2: $\hat{\gamma}_{i,j-1}$	0.026*	-0.002	0.036	0.003	0.071***
	(1.788)	(-0.107)	(1.496)	(0.206)	(2.899)
H3: λ	-0.002	-0.503***	-0.463**	-0.081	0.383*
	(-0.005)	(-4.134)	(-2.297)	(-0.527)	(1.661)
H5: $\bar{s}_2$	3.151***	15.036***	-4.502***	-12.137***	2.693**
	(6.156)	(17.488)	(-3.698)	(-14.985)	(2.109)
H7: $\Sigma s_2^+/\Sigma s_2$	0.078***	0.705***	-0.141***	-0.570***	0.174***
	(3.583)	(17.609)	(-3.019)	(-14.799)	(3.452)
Controls:					
Size	-0.151***	-0.147***	-0.133***	0.122***	0.206***
	(-17.519)	(-13.214)	(-8.395)	(11.370)	(10.917)
Foreign Sales	-0.000	0.089	-0.148	-0.035	-0.260*
	(-0.004)	(0.960)	(-1.143)	(-0.408)	(-1.793)
Intern. Inc.	0.003	-0.114	-0.107	-0.022	-0.125
	(0.045)	(-1.365)	(-0.881)	(-0.273)	(-0.964)
Leverage	0.008**	0.011	0.003	-0.004	-0.019*
	(2.373)	(1.388)	(0.399)	(-1.074)	(-1.834)
Quick Ratio	-0.005	0.016	-0.009	-0.002	0.010
	(-0.688)	(1.342)	(-0.865)	(-0.344)	(0.597)
Div. p. E.	-0.654***	-0.703***	-0.653***	0.701***	0.686***
	(-12.094)	(-9.424)	(-6.416)	(9.021)	(5.774)
R&D Sales	0.009**	0.010	0.021***	-0.011	-0.010
	(2.300)	(1.588)	(3.311)	(-1.247)	(-1.016)
Observations	22,846	6,628	4,553	6,579	5,086
R^2	0.108	0.146	0.117	0.106	0.126

Dependent variables: foreign exchange rate exposure as proxy for the current hedge ratio. 0.5% of the estimated exposures are winsorized on each end to account for outliners. Absolute values of the exposures are used for the first two models with all observations. For the latter, the sign of the exposure and the past exchange rate return is used to separate the sample into exporters (EX) and importers (IM) as well as past development of the exchange rate. All models are estimated using a linear dynamic panel system estimator that specifies a level as well as a difference equation and is based on Arellano and Bond (1991) and Arellano and Bover (1995). To obtain robust standard errors, we use the Windmeijer (2005) correction of the two-step GMM estimator. T-statistics are given in parentheses. The coefficients are tagged with the respective significance levels: * p<10%, ** p<5%, *** p<1%.

Table 5: Linear dynamic panel results of model hypotheses with regret aversion parameter

	All	Exporter		Importer	
	$\lvert\hat{\gamma}_{i,j}\rvert$	s_1^+	s_1^-	s_1^+	s_1^-
Model-derived variables and expected signs:					
H1: s_1	0.748	5.374***	-9.213***	-4.608***	6.517***
	(1.444)	(8.097)	(-10.838)	(-7.314)	(6.378)
H2: $\hat{\gamma}_{i,j-1}$	0.013	-0.013	-0.020	-0.021	0.047
	(0.536)	(-0.466)	(-0.424)	(-0.752)	(1.146)
H3: λ	-0.349**	-0.674**	-0.486	-0.134	0.159
	(-2.026)	(-2.325)	(-0.968)	(-0.800)	(0.292)
H4: ρ	0.002***	0.001***	0.082	-0.057	-0.001
	(14.538)	(13.843)	(1.200)	(-0.976)	(-0.056)
H5: $\bar{s}_2$	4.687***	15.369***	0.630	-11.074***	3.634*
	(4.920)	(7.912)	(0.336)	(-6.561)	(1.753)
H7: $\Sigma s_2^+/\Sigma s_2$	-0.037	0.723***	-0.153**	-0.474***	0.192***
	(-0.997)	(8.351)	(-2.556)	(-6.262)	(2.583)
Controls:					
Size	-0.131***	-0.096***	-0.116***	0.097***	0.176***
	(-10.168)	(-5.865)	(-4.624)	(5.335)	(6.552)
Intern. Inc.	0.045	-0.054	-0.243*	-0.020	-0.141
	(0.710)	(-0.583)	(-1.958)	(-0.212)	(-1.069)
Leverage	0.002	-0.002	0.004	-0.004	-0.012
	(0.489)	(-0.082)	(0.800)	(-0.603)	(-1.328)
Quick Ratio	-0.018	-0.014	-0.032**	0.012	0.048*
	(-1.533)	(-0.689)	(-2.422)	(0.627)	(1.873)
Div. p. E.	-0.648***	-0.707***	-0.673***	0.536***	0.730***
	(-7.853)	(-5.644)	(-4.362)	(3.703)	(4.546)
R&D Sales	0.025	0.223***	0.003	0.071***	-0.311***
	(0.963)	(5.421)	(0.668)	(3.724)	(-4.467)
Observations	5,800	1,427	1,307	1,566	1,500
R^2	0.060	0.110	0.003	0.085	0.068

Dependent variables: foreign exchange rate exposure as proxy for the current hedge ratio. 0.5% of the estimated exposures are winsorized on each end to account for outliners. Absolute values of the exposures are used for the first two models with all observations. For the latter, the sign of the exposure and the past exchange rate return is used to separate the sample into exporters (EX) and importers (IM) as well as past development of the exchange rate. All models are estimated using a linear dynamic panel system estimator that specifies a level as well as a difference equation and is based on Arellano and Bond (1991) and Arellano and Bover (1995). To obtain robust standard errors, we use the Windmeijer (2005) correction of the two step GMM estimator. T-statistics are given in parentheses. We leave out the foreign sales variable as this variable is used to specify the proxy of regret aversion parameter. The coefficients are tagged with the respective significance levels: * p<10%, ** p<5%, *** p<1%.

Table 6: Robustness check: risk aversion proxy

	All	Exporter		Importer	
	$\lvert\hat{\gamma}_{i,j}\rvert$	s_1^+	s_1^-	s_1^+	s_1^-
Model-derived variables:					
H1: s_1	0.398	2.032***	4.763***	-1.959***	-0.523
	(1.216)	(3.156)	(3.389)	(-2.812)	(-0.274)
H3: $\lambda(Age)$	-0.006*	-0.005	-0.010*	-0.002	0.008
	(-1.909)	(-0.987)	(-1.671)	(-0.377)	(0.970)
H3: $\lambda(RRA)$	-0.001	-0.012	-0.006	-0.010	-0.002
	(-0.265)	(-1.571)	(-0.841)	(-1.590)	(-0.209)
H5: $\bar{s}_2$	6.761***	8.289***	9.240***	-3.116***	-11.924***
	(10.380)	(6.080)	(6.983)	(-2.878)	(-6.313)
H7: $\Sigma s_2^+/\Sigma s_2$	0.133***	0.512***	-0.037	-0.468***	-0.058
	(5.317)	(8.535)	(-0.626)	(-8.795)	(-0.738)
Controls:					
Size	-0.124***	-0.163***	-0.375***	0.251***	-0.032
	(-4.153)	(-3.360)	(-5.533)	(5.676)	(-0.317)
Foreign Sales	-0.028	0.047	-0.283	0.176	-0.208
	(-0.166)	(0.153)	(-0.704)	(0.798)	(-0.376)
Intern. Inc.	-0.033	-0.196	0.003	0.012	0.242
	(-0.501)	(-1.258)	(0.019)	(0.102)	(1.268)
Leverage	0.004	0.020**	-0.004	0.007	0.008
	(0.878)	(2.012)	(-0.830)	(1.073)	(0.792)
Quick Ratio	-0.023	0.000	-0.017	0.020	0.095**
	(-1.432)	(0.011)	(-0.550)	(0.507)	(2.198)
Div. p. E.	-0.431***	-0.491**	-0.169	0.073	0.972***
	(-5.396)	(-2.565)	(-0.771)	(0.436)	(3.637)
R&D Sales	0.014**	-0.004	-0.107***	0.281**	-0.006***
	(2.413)	(-0.326)	(-4.319)	(2.359)	(-3.069)
Observations	6,255	1,700	1,392	1,782	1,381
R^2	0.072	0.119	0.073	0.014	0.052

Dependent variables: foreign exchange rate exposure as proxy for the current hedge ratio. 0.5% of the estimated exposures are winsorized on each end to account for outliners. Absolute values of the exposures are used for the first regression with all observations. For the latter, the sign of the exposure is used to separate the sample into exporters (EX) and importers (IM). For the last four regressions the past exchange rate return is also used to subdivide the sample. All regressions are estimated using a fixed-effects panel regression with robust and clustered standard errors on the company level. T-statistics are given in parentheses. The coefficients are tagged with the respective significance levels: * p<10%, ** p<5%, *** p<1%.

Table 7: Robustness checks: exposure estimation

	Quadratic		Non-parametric		Omitted Market	
	FE	Dynamic	FE	Dynamic	FE	Dynamic
Model-derived variables:						
H1: s_1	357.157***	412.859***	0.725***	0.172	-2.324***	-2.730***
	(13.370)	(10.276)	(3.026)	(0.588)	(-8.642)	(-8.358)
H2: $\hat{\gamma}_{i,j-1}$		-0.067***		0.018		0.159***
		(-5.232)		(1.298)		(10.297)
H3: λ	-0.650	-6.866	-0.196***	-0.198***	-0.201***	-0.148**
	(-0.094)	(-0.816)	(-3.698)	(-3.554)	(-3.399)	(-2.409)
H5: $\bar{s}_2$	832.983***	783.213***	6.425***	3.538***	-1.472***	-4.334***
	(18.600)	(12.971)	(14.820)	(6.731)	(-3.260)	(-7.738)
H7: $\Sigma s_2^+/\Sigma s_2$	41.776***	32.771***	0.151***	0.088***	-0.013	-0.099***
	(23.523)	(14.800)	(8.233)	(4.016)	(-0.655)	(-3.688)
Controls:						
Size	-34.186***	-16.945***	-0.245***	-0.159***	0.017	-0.071***
	(-16.433)	(-15.298)	(-14.063)	(-18.486)	(0.828)	(-8.109)
Foreign Sales	-32.577***	-1.659	-0.056	-0.025	0.473***	0.205**
	(-3.142)	(-0.210)	(-0.580)	(-0.385)	(4.178)	(2.460)
Intern. Inc.	-14.126***	-12.804*	0.036	0.008	0.589***	0.424***
	(-2.735)	(-1.879)	(0.750)	(0.130)	(9.045)	(5.107)
Leverage	0.880**	0.930*	0.004	0.007**	0.005	0.004
	(2.093)	(1.692)	(1.466)	(2.110)	(0.864)	(0.577)
Quick Ratio	1.083	0.656	-0.004	-0.005	-0.002	-0.003
	(1.554)	(0.792)	(-0.663)	(-0.873)	(-0.320)	(-0.462)
Div. p. E.	-40.190***	-60.718***	-0.424***	-0.670***	-0.677***	-0.763***
	(-5.834)	(-8.682)	(-6.925)	(-12.204)	(-7.864)	(-10.438)
R&D Sales	0.382	1.057	0.001	0.011***	0.002	0.003
	(0.739)	(1.555)	(0.121)	(2.667)	(0.529)	(0.799)
Observations	24,262	22,848	24,262	22,848	24,262	22,848
R^2	0.112	0.102	0.115	0.108	0.020	0.114

Dependent variables: foreign exchange rate exposure as proxy for the current hedge ratio. 0.5% of the estimated exposures are winsorized on each end to account for outliners. Absolute values of the exposures are used for all regressions. Exposures were calculated using a quadratic specification of the trade-weighted currency basket returns and a local polynomial non-parametric estimation (bandwidth of the standard error of each company's stock return divided by the square root of the observations per year) to account for non-linear exposure and the model of Adler and Dumas (1984) that does not include a market factor. All specifications are estimated using a fixed-effects panel regression with robust and clustered standard errors on the company level and using a linear dynamic panel system estimator that specifies a level as well as a difference equation and is based on Arellano and Bond (1991) and Arellano and Bover (1995). To obtain robust standard errors, we use the Windmeijer (2005) correction of the two-step GMM estimator. T-statistics are given in parentheses. The coefficients are tagged with the respective significance levels: * p<10%, ** p<5%, *** p<1%.

Table 8: Robustness checks: exposure estimation including regret aversion parameter

	Quadratic		Non-parametric		Omitted Market	
	FE	Dynamic	FE	Dynamic	FE	Dynamic
Model-derived variables:						
H1: s_1	291.628***	390.940***	0.478	0.578	-3.312***	-1.409**
	(5.295)	(5.732)	(0.897)	(1.079)	(-5.771)	(-2.174)
H2: $\hat{\gamma}_{i,j-1}$		-0.077***		0.021		0.198***
		(-3.429)		(0.803)		(7.362)
H3: λ	-13.339	-5.462	-0.308*	-0.282	-0.081	-0.046
	(-0.577)	(-0.311)	(-1.787)	(-1.638)	(-0.415)	(-0.191)
H4: ρ	0.490***	0.027	0.003***	0.001***	0.004***	0.002***
	(7.144)	(0.707)	(8.277)	(9.644)	(11.220)	(11.976)
H5: $\bar{s}_2$	822.876***	809.130***	6.690***	4.826***	-4.566***	-4.507***
	(6.981)	(6.207)	(6.352)	(4.783)	(-3.700)	(-3.829)
H7: $\Sigma s_2^+/\Sigma s_2$	21.119***	14.304***	0.021	-0.026	-0.278***	-0.255***
	(5.728)	(3.621)	(0.546)	(-0.683)	(-6.814)	(-5.518)
Controls:						
Size	-39.697***	-15.677***	-0.223***	-0.134***	0.003	-0.038**
	(-7.758)	(-8.858)	(-5.229)	(-9.902)	(0.057)	(-2.329)
Foreign Sales	-17.977	-4.583	-0.079	0.168	0.655***	0.291**
	(-0.940)	(-0.399)	(-0.431)	(1.610)	(3.018)	(2.198)
Intern. Inc.	-7.397	-5.083	0.025	0.011	0.633***	0.475***
	(-0.927)	(-0.654)	(0.304)	(0.162)	(6.514)	(4.591)
Leverage	0.053	0.183	-0.001	0.000	-0.001	0.003
	(0.141)	(0.403)	(-0.123)	(0.040)	(-0.260)	(0.342)
Quick Ratio	0.364	0.501	-0.024	-0.022*	-0.035*	-0.025*
	(0.187)	(0.303)	(-1.337)	(-1.762)	(-1.831)	(-1.728)
Div. p. E.	-39.081***	-48.035***	-0.340***	-0.639***	-0.721***	-0.951***
	(-3.485)	(-4.782)	(-3.339)	(-7.198)	(-4.033)	(-6.818)
R&D Sales	-0.823	2.662	-0.027	0.030	-0.045**	0.005
	(-0.360)	(0.947)	(-1.202)	(1.193)	(-2.519)	(0.208)
Observations	5,946	5,800	5,946	5,800	5,946	5,800
R^2	0.096	0.057	0.098	0.061	0.044	0.087

Dependent variables: foreign exchange rate exposure as proxy for the current hedge ratio. 0.5% of the estimated exposures are winsorized on each end to account for outliners. Absolute values of the exposures are used for all regressions. Exposures have been calculated using a quadratic specification of the trade-weighted currency basket returns and a local polynomial non-parametric estimation (bandwidth of the standard error of each company's stock return divided by the square root of the observations per year) to account for non-linear exposure and the model of Adler and Dumas (1984) that does not include a market factor. All specifications are estimated using a fixed-effects panel regression with robust and clustered standard errors on the company level and using a linear dynamic panel system estimator that specifies a level as well as a difference equation and is based on Arellano and Bond (1991) and Arellano and Bover (1995). To obtain robust standard errors, we use the Windmeijer (2005) correction of the two step GMM estimator. T-statistics are given in parentheses. The coefficients are tagged with the respective significance levels: * p<10%, ** p<5%, *** p<1%.

Table 9: Linear dynamic panel results of the model hypotheses with non-linear, quadratic estimation

	without regret aversion:				with regret aversion:			
	Exporter		Importer		Exporter		Importer	
	s_1^+	s_1^-	s_1^+	s_1^-	s_1^+	s_1^-	s_1^+	s_1^-
Model-derived variables and expected signs:								
H1: s_1	545.410***	-1410.646***	-599.516***	1040.565***	382.159***	-1147.989***	-373.855***	958.903***
	(14.840)	(-23.668)	(-15.227)	(18.692)	(6.701)	(-12.927)	(-5.626)	(11.639)
H2: $\hat{\gamma}_{i,j-1}$	-0.004	0.012	-0.002	0.017	-0.049**	0.050	-0.014	0.006
	(-0.402)	(0.618)	(-0.236)	(1.045)	(-2.193)	(1.382)	(-0.720)	(0.196)
H3: λ	-3.140	-21.193	-9.978	3.250	16.609	-54.237**	-8.264	-44.002
	(-0.313)	(-1.511)	(-0.935)	(0.192)	(0.418)	(-2.459)	(-0.304)	(-1.037)
H4: ρ					-0.002	6.609	0.900	-5.871***
					(-0.107)	(0.848)	(0.236)	(-3.738)
H5: $\bar{s}_2$	1848.840***	-550.812***	-1915.047***	467.952***	1784.914***	-474.402*	-2194.799***	437.434*
	(21.153)	(-3.472)	(-19.710)	(3.362)	(10.335)	(-1.677)	(-9.325)	(1.905)
H7: $\Sigma s_2^+/\Sigma s_2$	90.281***	22.960***	-85.451***	-10.380**	63.555***	21.950***	-60.502***	-8.183
	(20.310)	(5.265)	(-20.509)	(-2.333)	(8.401)	(3.362)	(-6.995)	(-1.208)
Controls:								
Size	-15.988***	-15.806***	12.534***	15.984***	-9.151***	-12.639***	8.475***	15.557***
	(-13.179)	(-9.691)	(9.707)	(10.111)	(-4.825)	(-5.556)	(3.253)	(6.659)
Foreign Sales	26.341***	-2.365	12.556	-3.884	19.423	7.728	-13.564	3.598
	(2.885)	(-0.179)	(1.193)	(-0.310)	(1.407)	(0.430)	(-0.826)	(0.157)
Intern. Inc.	-26.835***	-7.221	12.111	2.780	-10.844	-9.062	18.242*	3.918
	(-2.951)	(-0.605)	(1.219)	(0.229)	(-1.093)	(-0.667)	(1.703)	(0.282)
Leverage	0.744	0.763	-0.939	-1.793	1.028	0.014	-0.607*	-0.520
	(1.633)	(0.941)	(-1.518)	(-0.981)	(1.485)	(0.012)	(-1.882)	(-0.757)
Quick Ratio	2.165**	-0.531	-1.285	-0.607	2.456	-2.725	-0.376	3.589*
	(2.061)	(-0.357)	(-1.369)	(-0.578)	(0.870)	(-1.328)	(-0.141)	(1.675)
Div. p. E.	-58.156***	-53.162***	63.904***	57.916***	-44.002***	-55.321***	31.754**	64.794***
	(-8.013)	(-4.889)	(6.942)	(5.596)	(-3.723)	(-3.681)	(2.051)	(3.958)
R&D Sales	0.981	-0.258	-2.719**	-2.144***	19.429**	0.383	0.582	-1.314
	(1.092)	(-0.354)	(-2.082)	(-3.238)	(2.471)	(0.528)	(0.338)	(-0.058)
Observations	6,305	4,768	6,905	4,874	1,447	1,392	1,546	1,415
R^2	0.148	0.124	0.138	0.099	0.096	0.137	0.139	0.001

Dependent variables: foreign exchange rate exposure as proxy for the current hedge ratio. 0.5% of the estimated exposures are winsorized on each end to account for outliners. Absolute values of the exposures are used for the first two models with all observations. For the latter, the sign of the exposure and the past exchange rate return is used to separate the sample into exporters (EX) and importers (IM) as well as past development of the exchange rate. All models are estimated using a linear dynamic panel system estimator that specifies a level as well as a difference equation and is based on Arellano and Bond (1991) and Arellano and Bover (1995). To obtain robust standard errors, we use the Windmeijer (2005) correction of the two step GMM estimator. T-statistics are given in parentheses. The coefficients are tagged with the respective significance levels: * p<10%, ** p<5%, *** p<1%.

Table 10: Linear dynamic panel results of the model hypotheses without a market factor

	without regret aversion:				with regret aversion:			
	Exporter		Importer		Exporter		Importer	
	s_1^+	s_1^-	s_1^+	s_1^-	s_1^+	s_1^-	s_1^+	s_1^-
Model-derived variables and expected signs:								
H1: s_1	9.030***	-17.964***	-3.658***	0.856	7.366***	-19.349***	-3.392***	-1.655**
	(11.901)	(-14.508)	(-9.167)	(1.645)	(4.546)	(-7.489)	(-5.106)	(-2.025)
H2: $\hat{\gamma}_{i,j-1}$	0.097***	0.022	0.090***	0.182***	0.086	-0.046	0.152***	0.168***
	(3.736)	(0.669)	(5.235)	(9.439)	(1.583)	(-0.709)	(4.333)	(5.010)
H3: λ	0.051	-0.171	0.226**	0.226**	-0.116	0.184	0.111	0.034
	(0.391)	(-0.947)	(2.323)	(2.181)	(-0.186)	(0.343)	(0.349)	(0.076)
H4: ρ					0.976	0.024***	-0.002***	-0.001
					(0.769)	(4.062)	(-13.462)	(-0.027)
H5: $\bar{s}_2$	25.366***	2.450*	6.119***	12.031***	27.551***	2.541	10.709***	14.819***
	(19.977)	(1.829)	(5.957)	(9.527)	(9.338)	(1.239)	(5.558)	(6.410)
H7: $\Sigma s_2^+/\Sigma s_2$	1.258***	0.255**	0.277***	0.368***	1.665***	0.180	0.597***	0.399***
	(17.941)	(2.170)	(5.488)	(9.083)	(10.856)	(0.833)	(6.459)	(6.545)
Controls:								
Size	-0.132***	-0.099***	0.077***	0.080***	-0.116***	-0.130***	0.088***	0.042*
	(-8.210)	(-4.229)	(5.783)	(4.918)	(-4.040)	(-2.877)	(3.738)	(1.671)
Foreign Sales	0.370**	0.154	-0.078	-0.360***	0.720**	0.754*	-0.187	-0.328
	(2.430)	(0.650)	(-0.639)	(-2.599)	(2.408)	(1.731)	(-0.921)	(-1.631)
Intern. Inc.	-0.448***	-0.059	-0.590***	-0.112	-0.549***	-0.462*	-0.745***	-0.180
	(-2.605)	(-0.262)	(-4.752)	(-0.902)	(-2.681)	(-1.694)	(-4.707)	(-1.407)
Leverage	0.005	-0.008	-0.006	-0.008	0.015	-0.001	-0.004	-0.008
	(0.558)	(-0.551)	(-0.501)	(-1.037)	(0.197)	(-0.107)	(-0.384)	(-0.870)
Quick Ratio	0.030**	-0.011	-0.006	0.015	0.051	0.007	0.036**	0.023
	(2.070)	(-0.658)	(-0.706)	(1.318)	(0.996)	(0.314)	(1.962)	(1.326)
Div. p. E.	-0.803***	-0.331**	1.102***	0.750***	-0.780***	-0.096	1.320***	0.945***
	(-6.495)	(-2.056)	(10.850)	(5.990)	(-2.944)	(-0.342)	(6.665)	(4.758)
R&D Sales	0.020**	0.007	-0.004	-0.013	0.155***	0.210	0.036**	0.015
	(2.316)	(0.624)	(-0.494)	(-1.632)	(4.079)	(1.607)	(2.220)	(1.182)
Observations	4,046	1,945	9,164	7,697	714	432	2,279	2,375
R^2	0.104	0.050	0.113	0.147	0.090	0.047	0.038	0.082

Dependent variables: foreign exchange rate exposure as proxy for the current hedge ratio. 0.5% of the estimated exposures are winsorized on each end to account for outliners. Absolute values of the exposures are used for the first two models with all observations. For the latter, the sign of the exposure and the past exchange rate return is used to separate the sample into exporters (EX) and importers (IM) as well as past development of the exchange rate. All models are estimated using a linear dynamic panel system estimator that specifies a level as well as a difference equation and is based on Arellano and Bond (1991) and Arellano and Bover (1995). To obtain robust standard errors, we use the Windmeijer (2005) correction of the two-step GMM estimator. T-statistics are given in parentheses. The coefficients are tagged with the respective significance levels: * p<10%, ** p<5%, *** p<1%.

Table D.1: Linear dynamic panel results of the model hypotheses with nonlinear, non-parametric estimation

	without regret aversion:				with regret aversion:			
	Exporter		Importer		Exporter		Importer	
	s_1^+	s_1^-	s_1^+	s_1^-	s_1^+	s_1^-	s_1^+	s_1^-
Model-derived variables and expected signs:								
H1: s_1	6.196***	-10.017***	-5.322***	9.305***	5.297***	-9.507***	-5.243***	6.666***
	(16.027)	(-16.738)	(-14.473)	(12.995)	(7.974)	(-11.309)	(-8.198)	(6.391)
H2: $\hat{\gamma}_{i,j-1}$	0.015	0.036	0.016	0.067***	-0.011	-0.040	-0.026	0.059
	(0.920)	(1.437)	(1.019)	(2.718)	(-0.408)	(-0.906)	(-0.991)	(1.448)
H3: λ	-0.128	-0.131	0.031	0.227	-0.684***	-0.634	-0.104	0.096
	(-1.274)	(-0.761)	(0.352)	(1.414)	(-2.617)	(-1.393)	(-0.682)	(0.198)
H4: ρ					0.001***	0.022	-0.167	-0.008
					(8.904)	(1.205)	(-1.028)	(-0.087)
H5: $\bar{s}_2$	15.387***	-4.667***	-12.869***	2.191*	15.726***	-0.305	-11.760***	3.796*
	(17.458)	(-3.737)	(-14.843)	(1.672)	(8.043)	(-0.165)	(-6.432)	(1.830)
H7: $\Sigma s_2^+/\Sigma s_2$	0.764***	-0.182***	-0.609***	0.181***	0.763***	-0.171***	-0.511***	0.203**
	(18.513)	(-3.889)	(-15.225)	(3.481)	(9.053)	(-2.752)	(-6.289)	(2.563)
Controls:								
Size	-0.149***	-0.144***	0.130***	0.204***	-0.097***	-0.124***	0.110***	0.189***
	(-13.134)	(-8.580)	(11.391)	(11.024)	(-5.956)	(-4.964)	(5.635)	(6.643)
Foreign Sales	0.030	-0.192	-0.026	-0.206	0.100	0.216	-0.238	-0.324
	(0.328)	(-1.482)	(-0.285)	(-1.428)	(0.674)	(1.100)	(-1.384)	(-1.352)
Intern. Inc.	-0.065	-0.080	-0.043	-0.180	-0.044	-0.374**	0.031	-0.124
	(-0.721)	(-0.667)	(-0.495)	(-1.344)	(-0.430)	(-2.544)	(0.302)	(-0.846)
Leverage	0.006	0.000	-0.005	-0.023*	0.016	-0.003	-0.002	-0.010
	(1.000)	(0.064)	(-1.089)	(-1.831)	(0.542)	(-0.476)	(-0.300)	(-0.804)
Quick Ratio	0.015	-0.010	-0.000	0.009	-0.003	-0.042***	0.015	0.031
	(1.295)	(-1.052)	(-0.014)	(0.560)	(-0.133)	(-3.304)	(0.750)	(1.065)
Div. p. E.	-0.737***	-0.642***	0.670***	0.694***	-0.754***	-0.649***	0.490***	0.679***
	(-9.552)	(-6.271)	(8.272)	(5.783)	(-5.824)	(-4.028)	(3.294)	(4.197)
R&D Sales	0.014**	0.022***	-0.010	-0.009	0.227***	0.005	0.070***	-0.344***
	(2.206)	(2.954)	(-1.362)	(-0.951)	(4.162)	(1.206)	(3.784)	(-3.789)
Observations	6,608	4,620	6,602	5,022	1,433	1,331	1,560	1,476
R^2	0.147	0.125	0.108	0.127	0.009	0.005	0.087	0.026

Dependent variables: foreign exchange rate exposure as proxy for the current hedge ratio. 0.5% of the estimated exposures are winsorized on each end to account for outliners. Absolute values of the exposures are used for the first two models with all observations. For the latter, the sign of the exposure and the past exchange rate return is used to separate the sample into exporters (EX) and importers (IM) as well as past development of the exchange rate. All models are estimated using a linear dynamic panel system estimator that specifies a level as well as a difference equation and is based on Arellano and Bond (1991) and Arellano and Bover (1995). To obtain robust standard errors, we use the Windmeijer (2005) correction of the two-step GMM estimator. T-statistics are given in parentheses. The coefficients are tagged with the respective significance levels: * p<10%, ** p<5%, *** p<1%.

Figures

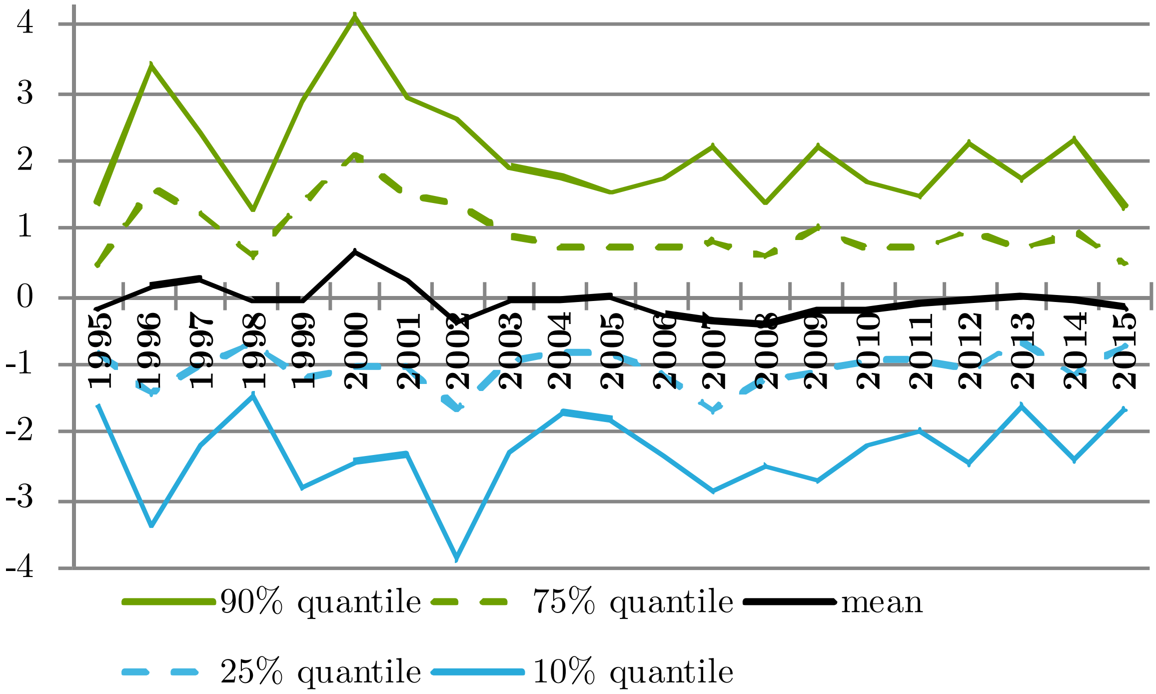

Figure 1: Cross-sectional distribution of exposures: quantiles and mean of exchange rate exposures for the years 1995 to 2015

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