

Retail Investors' Trading Behavior
in the Foreign Exchange Market
A Panel Duration Approach

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Abstract

This paper uses panel duration models to analyze the trading behavior of foreign exchange market investors. Proportional hazard as well as mixed proportional hazard specifications are suggested to capture the dynamics of roundtrip- and inactivity durations. Roundtrip durations are defined as the elapsed time from the entry into an investment in a currency pair to its exit, whereas inactivity durations are defined as time between two roundtrips. The proposed models serve on the one hand to investigate investors' trading behavior, and on the other hand as an instrument to verify the disposition effect (tendency to hold losers longer than corresponding winners). The proposed model set-up enriches the methods usually applied to investigate the disposition effect, since i) the time dimension is explicitly modelled, ii) the panel-structure of the data-set is exploited and iii) unobserved heterogeneity is taken into account through mixed proportional hazard specifications.

Our main findings can be summarized in the following way: i) the disposition effect varies with the size of the profit or loss obtained over a roundtrip, ii) for small profits and losses we find an inverse disposition effect, whereas for large profits and losses the usual disposition effect is found and iii) the disposition effect is more pronounced for overconfident investors.

JEL classification: G10, F31, C32

Keywords: Panel Duration Models, Retail Investors, Foreign Exchange Market, Behavioral Finance, Disposition Effect

1 Introduction

In this paper we introduce panel duration models to analyze the dynamic behavior of foreign exchange traders in a market microstructure framework. The paper can be understood as an attempt to investigate the trading dynamics in a kind of limit order book data-set where trading actions can be exactly assigned to the individual trader (trading activity record). After the availability of aggregated high frequency data-sets in the early 90s, such as the Trades and Quotes database of the New York stock exchange and the increasing availability of limit order book data-sets in the recent years, trading activity records where we can trace individual investors over time contain the most valuable form of market microstructure information. The description and the investigation of the data generating process in such a data-set requires different econometric techniques than the ones usually applied in high frequency data analysis. Panel duration models can serve as a tool to investigate the in time irregular behavior of investors over time. These kind of models are widely applied in the economic and econometric literature, but they have to our knowledge never been utilized in a market microstructure set-up. Examples of studies in different fields are Fahrmeir & Klinger (1998) and Visser (1987) (medicine); Jain & Vilcassim (1991) (marketing) and Lancaster (1979) and Heckmann & Borjas (1980) (investigation of employment and unemployment durations, labor economics).

From the trading activity record of OANDA FXTrade, we construct a data-set of roundtrip and inactivity durations of all active investors over the period from 1st October 2003 to 14th May 2004 (227 days). Roundtrip durations are defined as the elapsed time from entering into an investment in a currency pair until exiting it. Inactivity durations are defined as the time between two roundtrips, when the trader does not hold a position in a currency pair. We collect several trader specific explanatory variables over these durations, which allow us to control for individual trading preferences in our model set-up. We propose different proportional hazard models and mixed proportional hazard models – which enable us to account for unobserved heterogeneity – to capture the true nature of the data generating process.

Besides the property that these panel duration models are well suited to analyze trading behavior, they furthermore permit us to evaluate existing behavioral finance theories in a rigorous econometric model framework. We focus in our analysis on the disposition effect, which is the tendency that investors hold losing asset positions

longer than corresponding winning asset positions. The considered approach enriches the methods usually applied to investigate the disposition effect in several respects, since i) the time dimension is explicitly modelled, ii) the panel-structure of the data-set is exploited and iii) unobserved heterogeneity is taken into account. Furthermore, our data-set is perfectly suited to analyze the disposition effect, since in contrast to discount broker data-sets the number of trading instruments is highly limited. Therefore, we can trace investors' trading strategies separately for every trading instrument (currency pair) and in judging on trading strategies we do not need to account for different risk classes of the underlying instruments. Moreover, since we consider trading in the foreign exchange market, overnight effects are less severe and influences of short sale restrictions do not exist.

Our analysis is conducted for five currency pairs. From our trading activity record we choose, besides the four most active traded currency pairs which are EUR/USD (61.5%), GBP/USD (11.8%), AUD/USD (8.8%), USD/CHF (8.3%), the GBP/CHF (1.1%) currency pair for comparison reasons, since it does not involve USD. The GBP/CHF currency pair is the twelfth most actively traded.

The paper is organized as follows. In Section 2, we briefly review the literature concerning the disposition effect, we motivate our study and we derive several hypotheses on the relationship between individual trading characteristics and their influence on the disposition effect. In Section 3, we describe the construction of our data-set in detail and explain the trading mechanism on OANDA FXTrade. In section 4, we present the panel duration model specifications. Section 5 contains our empirical analysis and the verification of the hypotheses on the disposition effect. Finally, Section 6 concludes.

2 Disposition Effect

Motivation

The disposition effect – the tendency to hold losers longer than corresponding winners – is one of the most prominent and most analyzed behavioral bias which constitutes that investors do not behave rational in the sense of maximizing expected utility of final wealth. From a theoretical point of view the disposition effect, which was named by Shefrin & Statman (1985), can be grounded on the prospect theory of Kahneman & Tversky (1979). Therein investors are assumed to assess profits and losses relative to a reference point, which is usually considered to be a function of the assets' purchase prices. It is assumed that investors behave risk averse when their asset position has established a paper profit, and risk seeking when their position suffers from a paper loss.

From an empirical point of view most of the existing studies use aggregated data to analyze the disposition effect for the mean (representative) investor applying different methods to calculate the disposition effect. The early studies on investor behavior Lease, Lewellen & Schlarbaum (1974), Schlarbaum, Lewellen & Lease (1978a,b) and Shefrin & Statman (1985) as well as the studies of Badrinath & Lewellen (1991), Shapira & Venezia (2001) and Locke & Mann (2000), compare mean roundtrip durations of profitable and non-profitable investments. The studies of Odean (1998a) and Dhar & Zhu (2002) consider the difference between the proportion of profits and losses realized in a portfolio environment to investigate the disposition effect. Grinblatt & Keloharju (2001) apply Logit models to estimate the probabilities of closing positions conditional on whether the position is traded either in profits or in losses.

The analyses on the disposition effect can furthermore be categorized in studies focusing on individual investors' trading behavior in the stock market (Lease et al. (1974), Schlarbaum, Lewellen & Lease (1978a,b), Badrinath & Lewellen (1991), Odean (1998a), Chen, Kim, Nofsinger & Rui (2004), Feng & Seasholes (2004) and Ivkovich, Poterba & Weisbenner (2004)), on the difference between individual and professional or institutional investors in the stock market (Locke & Mann (2000), Grinblatt & Keloharju (2001), Shapira & Venezia (2001), Dhar & Zhu (2002) and Brown, Chappel, da Silva Rosa & Walter (2003)), on investors in the option and future markets (Heisler (1994) and Heath, Huddart & Lang (1999)), on investors

in the housing market (Genesove & Mayer (2001)), and on investors in experimental trading set-ups (Weber & Camerer (1998)). The studies of Kahneman (1992), Odean (1998a), Weber & Camerer (1998) and Barberis & Thaler (2003) discuss the choice of the correct reference point.

The results on the research on behavioral biases in general, and on the disposition effect in particular have several consequences for theoretical models relying on representative agents such as portfolio choice (Benartzi & Thaler (1995)) and asset pricing models Barberis, Huang & Santos (2001). Moreover, the studies of Grinblatt & Han (2005) and Shumway & Wu (2005) analyze how the disposition effect generates momentum and therefore affects stock prices. Coval & Shumway (2005) and Locke & Mann (2005) investigate whether and how behavioral biases, among them the disposition effect, affect prices or create trading costs.

Although these studies generate a tremendous interest in characterizing the disposition effect properly the econometric techniques applied in most of research seems to be underdeveloped. The disposition effect is related to the time (duration) between the opening to the closing of a position (roundtrip). Therefore it is surprising, that most of the research does not model this duration explicitly and does not make it conditional on individual traders characteristics and previous information. To our knowledge, only the studies of Feng & Seasholes (2004), Ivkovich et al. (2004) and Shumway & Wu (2005) try to model these roundtrip durations explicitly using intensity models. Including background variables on investors' characteristics they control for **observable** heterogeneity among investors. However, even these studies do not control for **unobservable** heterogeneity, they completely ignore the panel-structure of their data-sets and they do not provide convincing goodness-of-fit criteria for their model choice, which might render most of their results invalid.

Applying panel duration models and controlling for unobservable heterogeneity among investors, we try to cope with these critics. This approach does not only allow to investigate the exact form of the disposition effect conditional on investor types, individual investors' trading characteristics and time, it furthermore allows to investigate the timing of trading strategies of our investors using a rigorous econometric model framework. Panel duration models are widely applied in the literature. For example Lancaster (1979) and Heckmann & Borjas (1980) provide applications to unemployment durations, Fahrmeir & Klinger (1998) and Visser (1987) apply them for medical analysis and Jain & Vilcassim (1991) examine household purchase timing decisions. Excellent overviews on duration models are given in the textbooks

of Kalbfleisch & Prentice (1980) and Lancaster (1997) as well as in the survey article of van der Berg (2001). However, to our knowledge these kinds of models have never been applied before to analyze the trading behavior of individuals in a market microstructure setting.

Hypotheses

Since we apply panel duration models where we primarily model the hazard rate (intensity) of the roundtrip duration, we need to clarify the definition of the disposition effect for this approach.

Definition 1: Disposition Effect

The tendency to hold losers longer than corresponding winners, reformulated in terms of the hazard rate, is a smaller hazard rate (probability to leave the roundtrip state) for losses than for corresponding profits.

Note, that this definition only requires that for each loss amount there is a smaller hazard rate than for the corresponding profit amount. It does not require that the difference between hazard rates for losses and the hazard rate for profits is neither constant over the length of the holding period nor constant over the associated money amount. Before, we start to assess hypotheses on the relationship between the disposition effect and investors' characteristics, we need to check whether the proposed model framework is really necessary for these analyses. Therefore, we need to verify the following three crucial hypothesis:

Hypothesis H1.1

There is no unobservable heterogeneity among our investors.

Hypothesis H1.2

The hazard rate of a roundtrip duration does not depend neither on the length of pervious roundtrip durations nor on the length of previous inactivity durations.

Hypothesis H1.3

The baseline hazard rate of roundtrip and inactivity durations is constant over the length of these durations.

If we can reject all three hypothesis H1.1 to H1.3 our proposed model framework becomes indispensable. If for example, H1.2 and H1.3 cannot be rejected there would be less need to model the roundtrip durations explicitly using a survival ap-

proach. If H1.1 and H1.2 cannot be rejected there would be less need to consider a panel approach since a certain part of the correlation structure across our investors is modelled through the unobservable heterogeneity variable. If only H1.2 cannot be rejected one may use simpler duration models such as Feng & Seasholes (2004), Ivkovich et al. (2004) and Shumway & Wu (2005) to make inference on the disposition effect.

Several studies (Odean (1998a), Shapira & Venezia (2001) and Grinblatt & Keloharju (2001) just to name a few) document that the “average investor” exhibits the disposition effect and the studies of Odean (1998a), Ivkovich et al. (2004), Feng & Seasholes (2004) stress an tax argument (e.g. Stiglitz (1983) and Constantinides (1984)) that the disposition effect is diminished, disappears, or is inverted in the presence of taxes. However, Dhar & Zhu (2002) show that even in the absence of tax effects up to on fifth of their investors exhibit an inverse disposition effect. Following the tax argument of Stiglitz (1983) and Constantinides (1984) losses should be immediately realized after their occurrence and we can hypothesize that one should observe a diminished or an inverse disposition effect for small loss amounts. In addition, without relying on the tax argument, investors might want to insure themselves against large losses by submitting stop-loss orders with tight limits, which should yield again a diminished or an inverse disposition effect for small losses. On the other hand, adopting the usual convention of Glosten (1994) and Seppi (1997), roundtrips which are closed by special limit orders can be considered as roundtrips being completed by (temporarily) patient or uninformed investors. As outlined in the discussion below this should yield an even more severe disposition effect and less reduction or inversion. But our data-set consist of retail investors mainly, who usually do not have access to private information. Therefore the information argument might be invalid. However, we can still test the following hypotheses:

Hypothesis H2.1

The disposition effect is not constant over the region of profit and loss amounts.

Hypothesis H2.2

Especially, for small profits and losses there is a diminished or an inverse disposition effect.

Hypothesis H2.3

The effect of a diminished or an inverse disposition effect is even more pronounced if positions are closed by special limit orders (stop-loss, take profit).

Another focus of the literature concerning the disposition effect and further behavioral biases lies on the discrimination between the levels on which investors are prone for behavioral biases. Shapira & Venezia (2001) find that individual (less informed and less sophisticated) investors are more affected by the disposition effect than institutional investors, which support the statement of Ross (1999) that institutional investors are more rational. Dhar & Zhu (2002) find that wealthier, more experienced and professional investors exhibit a smaller disposition effect. However, Locke & Mann (2000), and Brown et al. (2003) provide evidence that intuitional and professional investors are subject to behavioral biases as well. A similar result is found for less sophisticated and experienced Chinese investors by Chen et al. (2004). They find that their investors are contemporaneously subject to several behavioral biases such as the disposition effect, overconfidence, representative biases and narrow framing. According to these findings we can hypothesize that investors which are more effected by other behavioral biases exhibit also a stronger form of the disposition effect. In particular, we want to test whether investors which are more overconfident, in the sense of being more self-attribution biased (Wolosin, Sherman & Till (1973)), exhibit a more severe form of the disposition effect. Therefore we propose to verification strategies:

i) De Bondt & Thaler (1995), Odean (1998b), Wang (1998) and Gervais & Odean (2001) analyze the relationship between overconfidence and trading volume. They find that overconfidence leads to unusual high trading volumes. Therefore we approximate a general degree of overconfidence with investors' trading volume and claim that investors with high trading volumes submit orders with relatively more unnecessary high volumes than investors who generally trade small volumes. Following this argument, we should observe a more pronounced disposition effect for investors with high trading volumes (big investors). On the contrary, one can argue that investors with higher trading volumes are simply wealthier and more sophisticated, which yield according to Dhar & Zhu (2002) a less pronounced disposition effect.

ii) we claim that investors become temporarily overconfident and in particular self-attribution biased, because of their past trading success and we approximate overconfidence by a variable capturing past trading success. Thus, we should observe that investors with temporarily more trading success should be more prone to the disposition effect. On the contrary, we can argue that past trading success is not a proxy for self-attribution bias but for trading experience, which then should yield

a less pronounced disposition effect (e.g. Chen et al. (2004)). Thus the following hypotheses can be verified:

Hypothesis H3

Overconfident investors exhibit a more pronounced disposition effect than investors being not overconfident.

This general hypothesis is verified by two subordinated hypothesis:

Hypothesis H3.1

Investors which trade with higher trading volumes exhibit a more pronounced disposition effect.

Hypothesis H3.2

Investors with temporarily high past trading success exhibit a more pronounced disposition effect.

3 Description of the Data-Set

Trading Mechanism on OANDA FXTrade

Our empirical analysis is based on a data-set which is constructed from the activity record of OANDA FXTrade. Before we describe our data-set in detail, we will briefly summarize the trading mechanism of OANDA FXTrade.¹ OANDA FXTrade is an 24-hours-7-days-per-week internet trading platform for mainly non-financial customers stated differently for retail investors. OANDA itself acts as a market maker and sets bid and ask quotes based on an external datafeed (crossing network) and on their own limit order book. Trading on OANDA is organized as margin trading, where a minimum initial margin of 2% on positions in the major currency pairs and 4% in all other currency pairs is required. A trader can submit market orders, limit orders and special limit orders (stop-loss, take profit) to the system. Limit orders are maintained up to one month and a trader may change submitted limits at any time without incurring an extra fee. Each trader possess a trading account on OANDA FXTrade, which is managed in 7 possible account currencies either USD, EUR, CHF, GBP, JPY, AUD or CAD. Direct transfers from or to a specific account can only be made in the respective account currency, for example you cannot transfer EUR from an USD account to a third party account directly.

Construction of the Data-Set

The data-set that is used in our analysis is constructed from the activity record of OANDA FXTrade, which ranges from 1st October 2003 to 14th May 2004 (227 days). Therein, all trading activity of 4893 different traders in a possible 30 currency pairs is recorded on a second by second basis. Table 1 in Appendix A overviews the entries in the activity record. Depending on the transaction type, we get information on the transaction prices (market orders, limit orders executed, stop-loss, take profit, margin call), on the bid and ask quotes (pending limit orders), on the transaction volume and, on the limits of stop-loss and take-profit orders. Moreover, we have information on the account currency of each trader and on each traders' invested start position per currency pair at 1st October 2003 00:00:00 (Eastern Standard Time).

For each trader we compute separately the respective currency pair durations from entering into a position to leaving it, i.e. the time he was invested in a specific

¹A more elaborate description can be found in Lechner & Nolte (2005).

currency pair. We refer henceforth to this duration as the roundtrip (state) duration. Furthermore, we calculate the durations for the period where the investor was not invested in the specific currency pair to which we refer as the inactivity (state) duration. Thus, we obtain an alternating series of roundtrip and inactivity durations. Moreover, we calculate several explanatory variables over these durations, which allow us to account for the individual trading behavior.² Figure 1 clarifies the panel structure of the constructed data-set. Our empirical analysis however, focuses only on five currency pairs: EUR/USD, GBP/USD, AUD/USD, USD/CHF, and GBP/CHF, which are always treated separately.

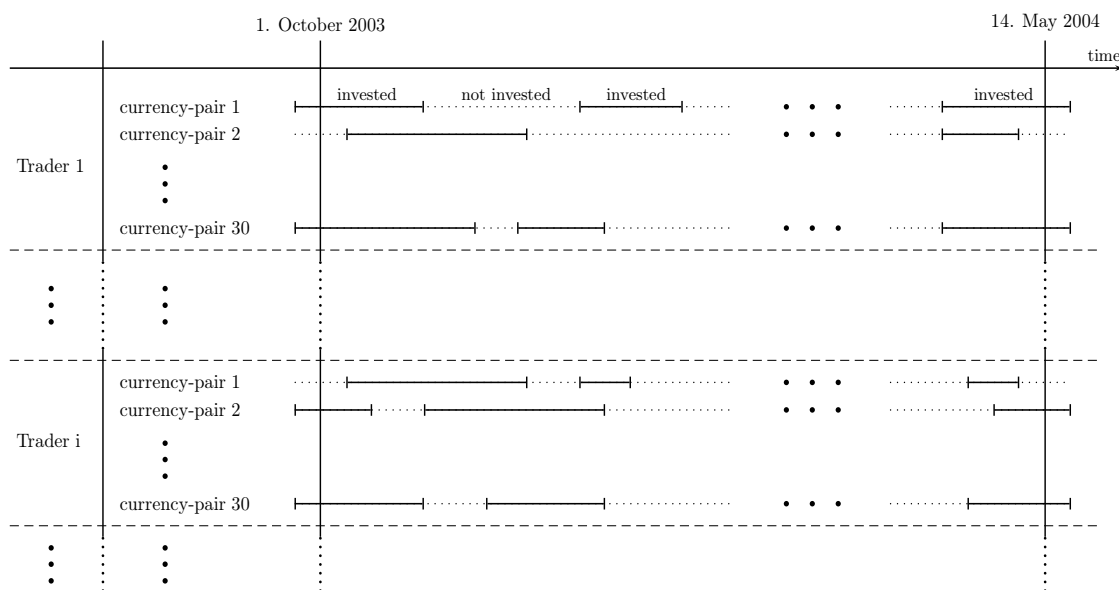


Figure 1: Structure of the panel data-set

²We refrain from describing these explanatory variables at this place, because they are explained in the empirical section in detail.

4 The Model

Our model needs to account for the following properties of the data-set:

- i) We need to model two alternating states, namely the roundtrip- and the inactivity state, where both states may be right censored at the end of our sampling period.
- ii) The model needs to be computationally tractable, since we have for example 641230 observations for the EUR/USD currency pair.

Therefore, we propose a completely parametric model with four states (roundtrip, inactivity, right censored roundtrip, right censored inactivity) using the following notation:

Let $i, i = 1, \dots, N$ denote the i^{th} trader. For the i^{th} trader we observe C_i duration cycles (spells), which are either roundtrip-, inactivity-, right censored roundtrip- or right censored inactivity- durations. Let $c, c = 1, \dots, C_i$ denote the c^{th} cycle of the i^{th} trader. Let us consider the transition to a particular state: We do not need to distinguish between the origin and the destination state due to the alternating behavior between roundtrip and inactivity states. Transitions from roundtrip to roundtrip as well as from inactivity to inactivity are excluded. The right censored states are modelled with 2 dummy censoring destinations, with separate hazard rates. Let $m = 1, \dots, M = 4$ denote the m^{th} state, with $m = 1$ the roundtrip state, $m = 2$ the inactivity state, $m = 3$ the right censored roundtrip state and $m = 4$ the right censored inactivity state.

With d_{cm}^i we denote the indicator function, which takes the value 1 if the i^{th} trader is in state m in the c^{th} cycle and 0 otherwise.

Let s_c^i denote the duration of the c^{th} cycle of the i^{th} trader and let t_c^i denote the calendar time at which the i^{th} trader entered the c^{th} cycle.

We can then denote the hazard rate of the i^{th} trader for leaving the m^{th} state in the c^{th} cycle with

$$\theta_{cm}^i(t_c^i, s_c^i), \quad (1)$$

and the corresponding integrated hazard with

$$z_{cm}^i(t_c^i, s_c^i) = \int_0^{s_c^i} \theta_{cm}^i(t_c^i, \nu) d\nu. \quad (2)$$

The log-likelihood is thus given by:

$$l = \sum_{i=1}^N \sum_{c=1}^{C_i} \sum_{m=1}^M (d_{cm}^i \ln \theta_{cm}^i(t_c^i, s_c^i) - z_{cm}^i(t_c^i, s_c^i)). \quad (3)$$

We estimated this model with four different specification of the hazard rates. In the first three versions the state dependent hazard rates are modelled and parameterized as proportional hazards in the following way:

$$\theta_{cm}^i(t_c^i, s_c^i) \equiv b^m(s) \exp(\gamma^m x_{ic}^m), \quad (4)$$

with $b^m(s)$ denoting a state specific, but cycle and individual unspecific, baseline hazard rate. Thus s denotes an arbitrary duration in the m^{th} state. x_{ic}^m denotes the vector of state specific explanatory variables of the i^{th} trader in the c^{th} cycle, and γ^m denotes the corresponding (state dependent) parameter vector. x_{ic}^m includes a constant and may include lagged durations.

All four versions have in common that the hazard rates of right censored durations are simply specified by the exponential model, which is based only on a constant term, i.e. in equation (4)

$$b^m(s) \equiv 1 \quad \text{and} \quad \gamma^m x_{ic}^m \equiv c_m \quad \text{for } m = 3, 4. \quad (5)$$

Furthermore, all three versions have in common that the explanatory variables for the inactivity state ($m = 2$) consist only of a constant c_2 as well. The baseline hazards for the roundtrip ($m = 1$) and the inactivity ($m = 2$) states are chosen from the same class for each of the four specifications.

In our first version, the assumption of an exponential model (baseline hazard equal to 1) is extended to the roundtrip ($m = 1$) and the inactivity ($m = 2$) state.

In our second version, we specify a Weibull model for equation (4), which is given by

$$b^m(s) \equiv \alpha_m s^{\alpha_m - 1} \quad \text{for } m = 1, 2. \quad (6)$$

The third version consists of a Box-Cox model for equation (4), i.e.

$$b^m(s) \equiv \alpha_m \exp((\alpha_m - 1)s^{(\beta_m)}) \quad \text{for } m = 1, 2, \quad (7)$$

where $s^{(\beta)} \equiv \frac{s^\beta - 1}{\beta}$ is the Box-Cox transformation. Note that in the case of the Box-Cox model, there is no explicit solution for the integrated hazard in equation (2) and the solution has to be obtained numerically.

Our fourth version can be considered as a mixed proportional hazard model, which accounts for unobserved heterogeneity among the traders. Here equation (2) is augmented by a multiplicative random variable v , which is considered to capture the unobserved heterogeneity. Thus, we obtain:

$$\theta_{cm}^i(t_c^i, s_c^i, v) \equiv v b^m(s) \exp(\gamma^m x_{ic}^m). \quad (8)$$

In our specification, we assume v to be Gamma distributed with mean 1 and variance σ^2 , i.e. $v \sim \text{Gamma}(1, \sigma^{-2})$. Furthermore, we assume

$$b^m(s) \equiv \alpha_m s^{\alpha_m - 1} \quad \text{for } m = 1, 2, \quad (9)$$

which is the Weibull model for $b^m(s) \exp(\gamma^m x_{ic}^m)$. Then the mixture of v with the Weibull model yields the Burr model³ for equation (8), i.e.

$$\theta_{cm}^i(t_c^i, s_c^i) \equiv \theta_{cm}^i(t_c^i, s_c^i, v) = \frac{\exp(\gamma^m x_{ic}^m) \alpha_m s^{\alpha_m - 1}}{1 + \sigma^2 \exp(\gamma^m x_{ic}^m) s^{\alpha_m}} \quad \text{for } m = 1, 2. \quad (10)$$

Note that σ^2 is common for the roundtrip and the inactivity state. A test for unobserved heterogeneity is therefore given by a test on $\sigma^2 = 0$, in which case the Burr model collapses to the Weibull model. Furthermore, the Burr model nests the Log-Logistic model for $\sigma^2 = 1$. The important advantage of the assumptions made above is that the mixture hazard rate (8) can be explicitly derived with respect to σ^2 . This enables us to maximize the log likelihood simply with one additional parameter and avoids stochastic integration methods to integrate v out of the log likelihood.

Let us now turn to the explanatory variables for the roundtrip state ($m = 1$). The model set-up proposed above allows us to describe, **conditional** on market microstructure explanatory variables and trader characteristics, the mechanism of switching between periods in which traders are invested in a certain asset (here: a currency pair) and in which they are not. This is an important property in itself, since based on these observations we might infer (at least we are able to describe) why investors step into a position or why they step out of it. Moreover, the model allows us to evaluate the hypotheses on the disposition effect raised in Section 2.

Before we verify these hypotheses explicitly we test the existence of a general disposition effect (a smaller hazard rate for losses than for corresponding gains) by including, in a first step, the profit or loss over a roundtrip obtained by the i^{th} investor in the c^{th} cycle as an explanatory variable, henceforth denoted as $pl_i \equiv pl_i^c$ and defined by the following logarithmic transformation:

$$pl_i \equiv \begin{cases} \ln(1 + p_i) & \text{if } p_i > 0 \\ 0 & \text{if } p_i = 0 \\ -\ln(1 - p_i) & \text{if } p_i < 0, \end{cases} \quad (11)$$

where p_i denotes the untransformed profit or loss in the base currency, which is e.g. for the EUR/USD currency pair EUR. Note, that we suppress for the ease of notation the cycle specific index c from now on.

³Compare Lancaster (1997).

To control for observable heterogeneity among investors and to verify hypotheses H1.1 to H1.3, we include in a first step for trader i the following explanatory variables: the logarithmic maximum absolute volume measured in the base currency during a roundtrip, henceforth denoted as vo_i ; a dummy variable dco_i for the complexity of the trading strategy, which is equal to 1 if the roundtrip's trading strategy consists of more than 2 (open and close position) trades and 0 otherwise; a dummy variable do_i (dc_i) denoting whether the position is opened (closed) with a limit order; a dummy variable ds_i denoting whether the trader goes short in the base currency; a dummy variable da_i denoting whether the trader has EUR as the account currency; the logarithmic duration of the previous roundtrip state s_i^{1c-1} , and the logarithmic duration of the previous inactivity state s_i^{2c-1} .

The above mentioned explanatory variables may change from cycle to cycle, but they are time invariant with respect to the duration of a specific cycle. Thus, for the roundtrip state ($m = 1$) $\gamma^m x_{ic}^m = \gamma^m x_i^m$ becomes

$$\begin{aligned} \gamma^1 x_i^1 = & c_1 + \gamma_{pl} pl_i + \gamma_{vo} vo_i \\ & + \gamma_{dco} dco_i + \gamma_{do} do_i + \gamma_{dc} dc_i + \gamma_{ds} ds_i + \gamma_{da} da_i + \gamma_{s1} s_{ic-1}^1 + \gamma_{s2} s_{ic-1}^2. \end{aligned} \quad (12)$$

This first regression set-up is capable to answer the question whether a general disposition effect exists in which case γ_{pl} should be greater than 0, which means that the probability of leaving the roundtrip state would be lower for losses than for corresponding gains. The value of $\gamma_{pl} > 0$ would give a quantification of the size of the disposition effect.

In the second set-up we want to verify hypotheses H2.1 to H3.2 and we need to ask i) how exactly the disposition effect changes with the size of the profit or loss, ii) how this change is related to overconfident (self attribution biased) investors, where overconfidence is once measured by trading volume (little, much) and once by a variable which reflects the past trading success and iii) whether the disposition and the before mentioned effects are different for roundtrips which are closed by stop-loss or take-profit (special limit orders) orders. Therefore, we augment equation (12) in several respects using the following explanatory variables. Let

$$pr_i \equiv \begin{cases} pl_i & \text{if } pl_i > 0 \\ 0 & \text{otherwise,} \end{cases} \quad (13)$$

and

$$lo_i \equiv \begin{cases} pl_i & \text{if } pl_i < 0 \\ 0 & \text{otherwise,} \end{cases} \quad (14)$$

denote the variables for a logarithmic profit and a logarithmic loss in a roundtrip of the i^{th} investor. Furthermore, let dpr_i (dlo_i) denote the dummy variable of whether a roundtrip yields a profit (loss). Let dsm_i (dbi_i) denote the dummy variable of whether the i^{th} investor is small (big) and generally invests little (much) money. Thereby we consider an investor as small if the maximum absolute volume invested during a roundtrip is smaller than 2500 units of the corresponding base currency for all roundtrips, and he is considered as big if the maximum absolute volume invested during a roundtrip is at least once greater or equal to 250,000 units of the corresponding base currency. Using this convention, we defined depending on the currency pair between 22% to 30% (5% to 8%) of the investors to be small (big). With doc_i we denote the dummy variable which represents the past trading success of the i^{th} investor. We define doc_i to be equal to 1 if the i^{th} investor obtained gains in each of his last two roundtrips.⁴ Furthermore, let dsl_i denote the dummy variable of whether the roundtrip is closed with a special limit order (stop-loss, take profit). In the second regression set-up, we use the following specification including interaction terms to analyze the before raised questions:

$$\begin{aligned}
\gamma^1 x_i^1 &= c_1 \\
&+ \gamma_{dpr} dpr_i + \gamma_{dprdsm} dpr_i dsm_i + \gamma_{dprdbi} dpr_i dbi_i + \gamma_{dprdoc} dpr_i doc_i + \gamma_{dprdsl} dpr_i dsl_i \\
&+ \gamma_{dlo} dlo_i + \gamma_{dlodsm} dlo_i dsm_i + \gamma_{dlodbi} dlo_i dbi_i + \gamma_{dlodoc} dlo_i doc_i + \gamma_{dlodsl} dlo_i dsl_i \\
&+ \gamma_{pr} pr_i + \gamma_{prdsm} pr_i dsm_i + \gamma_{prdbi} pr_i dbi_i + \gamma_{prdoc} pr_i doc_i + \gamma_{prdsl} pr_i dsl_i \\
&+ \gamma_{lo} lo_i + \gamma_{lodsm} lo_i dsm_i + \gamma_{lodbi} lo_i dbi_i + \gamma_{lodoc} lo_i doc_i + \gamma_{lodsl} lo_i dsl_i \\
&+ \gamma_{pr^2} pr_i^2 + \gamma_{lo^2} lo_i^2 \\
&+ \gamma_{vo} vo_i + \gamma_{dco} dco_i + \gamma_{do} do_i + \gamma_{dc} dc_i + \gamma_{ds} ds_i + \gamma_{da} da_i + \gamma_{s1} s_{ic-1}^1 + \gamma_{s2} s_{ic-1}^2 \quad (15) \\
&\equiv \gamma^{1pl} x_i^{1pl} + \gamma^{1rest} x_i^{1rest}.
\end{aligned}$$

The constant c_1 captures the effect of a zero-profit roundtrip on the hazard. The parameters in the second and the third row represent shifts of the constant term given the specific dummy (interaction) variable. The parameters in the fourth and fifth row represent the effect of an increasing profit or loss and their interactions on the roundtrip hazard, whereas the parameters in the sixth row represent the effect of an increasing squared profit or loss. These profit and loss related parameters, and correspondingly their explanatory variables, are summarized by γ^{1pl} and x_i^{1pl} .

⁴The results with respect to this variable do not change qualitatively if past trading success is measured by the success in more than the two last roundtrips. Since we need to initialize the doc_i variable at the beginning of our data-set, considering only the two last roundtrips is the optimal choice, otherwise we would lose even more observations due to the initialization.

The parameters in the second to last row, which we summarize by $\gamma^{1rest} (x_i^{1rest})$, capture further observable heterogeneity among investors as described above for the first regression set-up, which is of course nested in this specification.

5 Empirical Analysis

The empirical analysis is carried out for 5 currency pairs. In the main body of the text we report on the results for the EUR/USD currency pair, which is by far the most active traded in our activity record. For comparison reasons, and to show the robustness of our findings we also analyze the GBP/USD, the AUD/USD, and the USD/CHF currency pairs, which are in terms of trading activity number 2, 3 and 4. In addition, we analyze the GBP/CHF currency pair which is number 12 in terms of trading activity, but does not include USD as the base or counter currency. The corresponding results for these 4 currency pairs are reported in Appendix B.

Descriptive Statistics

For the trading in the EUR/USD currency pair, we first analyze the descriptive statistics of the durations in the roundtrip, the inactivity, and both right censored states. In the raw data-set the durations are available on a second by second basis. In our analysis we scale them into hours. Table 1 summarizes the descriptive statistics for the durations.

EUR/USD	durations in hours			
	roundtrip	inactivity	cens. roundtrip	cens. inactivity
observations	319882	317303	899	3146
mean	11.290	22.704	647.58	988.27
std. deviation	69.332	122.95	954.80	1229.4
skewness	20.435	15.639	1.8996	1.4881
kurtosis	660.41	354.49	6.7110	4.6235
minimum	0.0003	0.0003	5.4716	3.2619
1% Quantile	0.0058	0.0016	9.3991	9.4766
5% Quantile	0.0191	0.0047	11.229	12.989
10% Quantile	0.0363	0.0094	13.399	14.205
25% Quantile	0.1141	0.0433	25.946	43.907
50% Quantile	0.4486	0.4047	182.67	419.89
75% Quantile	2.4061	6.6769	1023.7	1622.8
90% Quantile	15.630	42.210	2074.8	2802.9
95% Quantile	46.568	91.198	2238.3	3731.5
99% Quantile	191.25	405.46	4463.1	5050.1
maximum	4233.8	5235.5	5262.3	5390.9

Table 1: Descriptive statistics of the durations per state for the EUR/USD currency pair. The sample ranges from 1st October 2003 00:00:00 (EST) to 14th May 2004 23:59:59 (EST), which are 227 full days (5448 hours).

The first observation that should be made is that the durations in the right censored states possess completely different dynamics in comparison to their non censored counterparts. This justifies the separate investigation of these states. Furthermore, we see that the distributions of the durations in the roundtrip and the inactivity state are highly positive skewed, with a mean (median) of 11.3 (0.45) hours for the roundtrip state and 22.7 (0.40) hours for the inactivity state. Similar pictures emerge for the 4 less frequently traded currency pairs under investigation. The corresponding descriptive results are given in Table 7 and Table 8 in Appendix B. It turns out that for all considered currency pairs the mean and median duration of a roundtrip state is much smaller (up to 3 times) than the mean and median duration of an inactivity state.

Let us now consider the descriptive statistics of the explanatory variables, which are given in Table 2 as well as Tables 9 and 10 in the Appendix B. In the last column of these tables we report the mean of the considered dummy variables. Over the 4 most actively traded currency pairs a very similar picture emerges, whereas for the GBP/USD, which is the least liquid in our sample, slightly different numbers can be observed. These numbers are stated in parenthesis in the following explanation. Around 20% (25%) of the considered roundtrips are subject to a non-trivial (complex) trading strategy, which consists not only of one trade to open the position and another one to close it. Between 11% to 16% (27%) of all roundtrips are opened with a limit order, whereas around 38% (48%) of all roundtrips close with a limit order. Between 43% and 48% (39%) of all roundtrips start with a position in which the base currency is sold and then the counter currency is bought. Approximately 9% of the traders in all 5 currency pairs manage their account in EUR. Between 22% to 30% (50%) of the traders are considered as small investors and between 5% to 8% (2%) as big investors (overconfident or wealthy). Approximately 37% of the roundtrips are initiated by traders, which we consider to be temporarily overconfident or sophisticated due to their performance in the last two roundtrips. Approximately 36% (42%) of all roundtrips are closed by special limit orders (stop-loss and take profit) so that it turns out that only about 2% (6%) of the roundtrips are closed by limit orders which are not special. All these figures are presented to emphasize the heterogeneity of our investors and of our investors' trading strategies and they are included in the regression set-up to account for these heterogeneity and to verify the hypotheses raised in Section 2.

In the second and third columns of Tables 2, 9 and 10, the descriptive statistics of the profit and loss per roundtrip as well as the maximum volume measured in the base

currency involved in a roundtrip is stated. Please note that these numbers are raw numbers and they are included in the regression set-up by applying a logarithmic transformation as described in equation (11). It turns out that the profit and loss distributions possess for all 5 currency pairs a high overkurtosis, which is similar to the overkurtosis pattern usually found in the analysis of equally spaced asset-returns. However, the other common stylized fact of left skewness can only be found for the EUR/USD and the AUD/USD currency pairs, whereas the profit and loss distribution for the remaining currency pairs is highly right skewed. Furthermore, the minimum and maximum profits and losses, together with the maximum volume invested during a roundtrip, suggest that a few “bigger or professional” players trade on OANDA FXTrade as well.

Columns 4 to 6 of the considered tables report the descriptive statistics of the durations of a roundtrip, separated into roundtrips which end with a loss, a zero profit or a profit. These numbers allow us to investigate the **unconditional** disposition effect among our investors. For the 4 most actively traded currency pairs we observe that the mean duration of a roundtrip which yields a profit is usually between 2 to 5 hours longer than the mean duration of a roundtrip yielding a loss, which is in contrast to the plain disposition effect. Only for the GBP/USD, the mean loss duration is about 7 hours longer than the mean profit duration. Having a more detailed look at the duration distribution of roundtrips with profits in comparison to the duration distribution of roundtrips with losses by considering the corresponding quantiles, we observe the following: Up to the 90% (50% for AUD/USD) quantile of the distributions the duration of a roundtrip yielding a loss is greater than the duration of a roundtrip yielding a profit, which is again in line with the disposition effect. For the GBP/USD this is true for all quantiles. This observation shows that even the **unconditional** disposition effect is not constant in the size of the considered profits or losses. Since these are just unconditional (with respect to further explanatory variables) descriptive statistics, we refrain from providing test statistics that test for the significance of these differences. We rather refer to the estimation results of the panel duration models, where we test for the disposition effect and for the form of the disposition effect in a rigorous way.

EUR/USD # investors: 4045	profit & loss	volume in base ccy	durations in hours			dummy variable	mean
			loss	zero- profit	profit		
observations	319882	319882	180724	13197	125961	complex strategy	0.1968
mean	-10.452	45251.8	10.491	1.8582	13.426	opening limit order	0.1108
std. deviation	3100.2	319620	60.863	12.255	82.837	closing limit order	0.3785
skewness	-50.331	60.1434	22.074	22.231	17.804	short in base ccy	0.4743
kurtosis	44345	7554.845	811.73	714.97	482.21	account in EUR	0.1048
minimum	-809400	1	0.0003	0.0003	0.0003	small investor	0.2272
1% Quantile	-620	2	0.0086	0.0044	0.0039	big investor	0.0813
5% Quantile	-90	90	0.0233	0.0136	0.0153	overconfident investor	0.3574
10% Quantile	-28	200	0.0417	0.0239	0.0314	special limit order closing	0.3656
25% Quantile	-2.3492	1000	0.1256	0.0628	0.1075		
50% Quantile	0.1450	5000	0.4872	0.1917	0.4447		
75% Quantile	5	20000	2.7117	0.6286	2.3501		
90% Quantile	32.500	70000	16.620	2.1870	16.295		
95% Quantile	91.318	149000	46.478	5.0497	51.834		
99% Quantile	600	800000	169.43	35.717	261.45		
maximum	688400	53000000	4031.2	524.88	4233.8		

Table 2: Descriptive statistics of the explanatory variables for the EUR/USD currency pair. The sample ranges from 1st October 2003 00:00:00 (EST) to 14th May 2004 23:59:59 (EST), which are 227 full days (5448 hours).

Estimation Results

We now report the estimation results of our four model specifications described in detail in Section 4. Again, the main body of the text contains only the tables for the EUR/USD currency pair, whereas the corresponding tables for the remaining four currency pairs are included in the Appendix B.

Specification without Interaction Terms (Hypotheses H1.1 to H1.3)

We first present the estimation results where the explanatory variables are chosen according the specification in equation (12). Table 3 and Table 11 in Appendix B summarize the estimation results. All estimates are obtained by maximum likelihood estimation. We compute for each specification two sets of residuals to verify the chosen model specification. Since for each trader each cycle specific integrated hazard $z_{cm}^i(t_c^i, s_c^i) = \int_0^{s_c^i} \theta_{cm}^i(t_c^i, \nu) d\nu$ is i.i.d. unit exponentially distributed, given the correct specification of $\theta_{cm}^i(t_c^i, \nu)$, we compute for each trader and each cycle the estimated

integrated hazards $\hat{z}_{cm}^i(t_c^i, s_c^i)$, which are asymptotically i.i.d. unit exponentially distributed as well. Thus, under the correctly specified model

$$\hat{\varepsilon}_{cm}^i \equiv 1 - \hat{z}_{cm}^i(t_c^i, s_c^i) \quad (16)$$

has zero mean and a unit variance.

For all four model specifications, as the first set of residuals, we construct a series of joint (pooled) residuals $\hat{\varepsilon}_j$, where we pool the $\hat{\varepsilon}_{cm}^i$ with respect to individuals i , cycles c , and states $m = 1, 2$. Note, we do not account for the right censored states. Furthermore, we construct state (only state 1 and 2) dependent residuals $\hat{\varepsilon}_j^m$, $m = 1, 2$, where we pool the $\hat{\varepsilon}_{cm}^i$ with respect to individuals i and cycles c . The property that the series $\hat{\varepsilon}_j$ and $\hat{\varepsilon}_j^m$, $m = 1, 2$ have a zero mean and a unit variance is retained. Moreover, the corresponding series of pooled integrated hazards \hat{z}_j and \hat{z}_j^m , $m = 1, 2$ are still i.i.d. unit exponentially distributed, under the correct model specification.

As the second set of residuals, we construct individual specific residuals (both state independent and state dependent) $\hat{\varepsilon}_i$ and $\hat{\varepsilon}_i^m$, $m = 1, 2$, where we take the mean over the cycle (and state), i.e.

$$\hat{\varepsilon}_i \equiv \frac{1}{\#m} \sum_m \hat{\varepsilon}_i^m \quad \text{and} \quad \hat{\varepsilon}_i^m \equiv \frac{1}{\#c} \sum_c \hat{\varepsilon}_{cm}^i. \quad (17)$$

Note that these residuals still have mean zero and unit variance, since theoretically the computation involves the sum of i.i.d. unit exponential random variables (under the correct specification), whose convolution is Erlangen distributed with mean and variance equal to the number of summands. These individual specific residuals give an insight into the heterogeneity across traders.

In Table 3 we give the estimates of the four model specifications for the EUR/USD currency pair. In terms of the log-likelihood function, the Burr model seems to be the best fit of our duration panel data. The second best model, which furthermore has one parameter more than the Burr- model is the Box-Cox model. The Weibull model, with one parameter less than the Burr- model takes the third place. The by far worst fit is provided by the exponential- model. Considering the log-likelihood and the variances of the different residuals in the exponential model, we have to assert that the exponential model is not flexible enough to capture the true nature of the data generating process. The variances are very far away from being equal to one. The means as well as the variances of the individual specific residuals indicate that there is much heterogeneity among traders, which cannot be explained by the exponential specification.

State	Parameter	Exponential Model	Weibull Model	Box-Cox Model	Burr Model
State 1 (Round-trip)	c_1	-1.865 (.0805)	-0.198 (.0355)	0.217 (.0394)	1.181 (.0946)
	γ_{pl}	0.033 (.0036)	0.007 (.0014)	0.000 (.0012)	-0.021 (.0036)
	γ_{vo}	0.035 (.0086)	0.007 (.0038)	0.005 (.0037)	-0.006 (.0079)
	γ_{s1}	-0.279 (.0059)	-0.170 (.0029)	-0.161 (.0028)	-0.375 (.0078)
	γ_{s2}	-0.074 (.0044)	-0.043 (.0018)	-0.042 (.0017)	-0.102 (.0044)
	γ_{dco}	-1.767 (.0391)	-0.865 (.0187)	-0.749 (.0161)	-1.713 (.0422)
	γ_{do}	-0.274 (.0444)	-0.151 (.0186)	-0.140 (.0170)	-0.282 (.0437)
	γ_{dc}	-0.011 (.0270)	-0.128 (.0131)	-0.178 (.0132)	-0.528 (.0323)
	γ_{ds}	0.092 (.0250)	0.051 (.0078)	0.045 (.0070)	0.054 (.0137)
	γ_{da}	0.108 (.0714)	0.063 (.0305)	0.063 (.0292)	0.144 (.0563)
	α_1	–	0.475 (.0021)	0.423 (.0029)	1.056 (.0173)
β_1	–	–	0.132 (.0024)	–	
	σ^2	–	–	–	1.416 (.0430)
State 2 (Inactivity)	c_2	-3.122 (.0254)	-0.307 (.0148)	0.102 (.0235)	0.701 (.0596)
	α_2	–	0.329 (.0018)	0.257 (.0031)	0.617 (.0107)
	β_2	–	–	0.034 (.0014)	–
State 3	c_3	-6.473 (.0491)	-6.472 (.0491)	-6.473 (.0491)	-6.473 (.0491)
State 4	c_4	-6.895 (.0222)	-6.896 (.0222)	-6.895 (.0222)	-6.896 (.0222)
observations		641230			
mean log-likelih.		-3.41390	-1.85709	-1.77393	-1.76658
Residual Analysis					
Joint:					
Mean ($\hat{\epsilon}_j$)		0.0000	0.0000	0.0000	0.0000
Variance ($\hat{\epsilon}_j$)		33.4259	1.6447	1.0935	0.8670
Mean ($\hat{\epsilon}_i$)		-2.5984	-0.5825	-0.3917	-0.3890
Variance ($\hat{\epsilon}_i$)		48.4779	1.2748	0.3013	0.2953
State 1:					
Mean ($\hat{\epsilon}_j^1$)		0.0000	0.0000	0.0000	-0.0024
Variance ($\hat{\epsilon}_j^1$)		37.4910	2.0117	1.3406	0.9406
Mean ($\hat{\epsilon}_i^1$)		-1.3792	-0.3846	-0.2319	-0.2870
Variance ($\hat{\epsilon}_i^1$)		48.4537	0.9466	0.3034	0.3470
State 2:					
Mean ($\hat{\epsilon}_j^2$)		0.0000	0.0000	0.0000	0.0024
Variance ($\hat{\epsilon}_j^2$)		29.3278	1.2748	0.8444	0.7927
Mean ($\hat{\epsilon}_i^2$)		-4.1904	-0.8329	-0.5864	-0.5166
Variance ($\hat{\epsilon}_i^2$)		169.0303	2.0039	0.7925	0.5844

Table 3: Estimation Results for the EUR/USD currency pair, c_m is the constant, γ_{pl} corresponds to profits, γ_{vo} to volume, γ_{s1} to duration of previous roundtrip state, γ_{s2} to duration of previous inactivity state, γ_{dco} to complex trading strategies, γ_{do} to limit order in opening, γ_{dc} to limit order in closing, γ_{ds} to short in EUR, γ_{da} to account in EUR. $\alpha_m, \beta_m, \sigma^2$ are parameters of the (baseline) hazard. Values in parenthesis () report the corresponding standard deviation. **Bold** numbers denote coefficients, which are not significant on the 5% level.

In terms of the log-likelihood, the step from the exponential- (-3.41390) to the Weibull model (-1.85709) is the largest one, whereas the steps from the Weibull to the Box-Cox- and further to the Burr- model are much smaller. For the Weibull model and the Box-Cox model the variances of the pooled residuals $\hat{\varepsilon}_j$ are larger than one, whereas for the Burr model they are smaller than one. This observation holds also for the roundtrip state (state 1) residuals. The variance of the Box-Cox model pooled residuals $\hat{\varepsilon}_j$ are closest to one, whereas the variance of Burr- model pooled residuals $\hat{\varepsilon}_j^1$ for the roundtrip state, which is the most important in our analysis, is closer to one. These observations are supported by the shape of the QQ-plots in Figure 3. There we plotted the quantiles of the pooled integrated hazards of the roundtrip state against the quantiles of the unit exponential distribution. Under the null of a correctly specified model, the plotted points should lie on the angel-bisection line. For all four models, we have to certify that the complete data generating dynamics cannot be captured by the chosen specifications. A similar picture emerges when we look at the QQ-plot of the completely pooled integrated hazards.

The QQ-plot and the value of the log-likelihood indicate altogether that the Burr-model is the model that suites the dynamics of the data best. However, the shape of the QQ-plot suggests that even the Burr- model is not flexible enough to capture the true nature of the data completely. The means and the variances of the individual specific residuals ($\hat{\varepsilon}_i$) (both state dependent and state independent) for all four model specifications indicate that there is a lot of heterogeneity left among the traders which cannot be captured by the proposed specifications.

Figure 2 depicts the estimated baseline hazards of the roundtrip state for our four model specifications. The Burr model hazard, which theoretically would allow for non-monotonic behavior of the baseline⁵ (unconditional) hazard, is monotonically decreasing as well. The interpretation is that with an increasing duration in the roundtrip state, the unconditional probability of leaving it is decreasing. This observations yield a clear rejection of hypothesis H1.3.

⁵Note, that the term baseline hazard is typically reserved for a proportional hazard model set-up and that the Burr model does not belong to this class. However, for reasons of convenience we refer to the Burr hazard with $\exp(\gamma^m x_i^m) \equiv 1$ as the (Burr) baseline hazard as well.

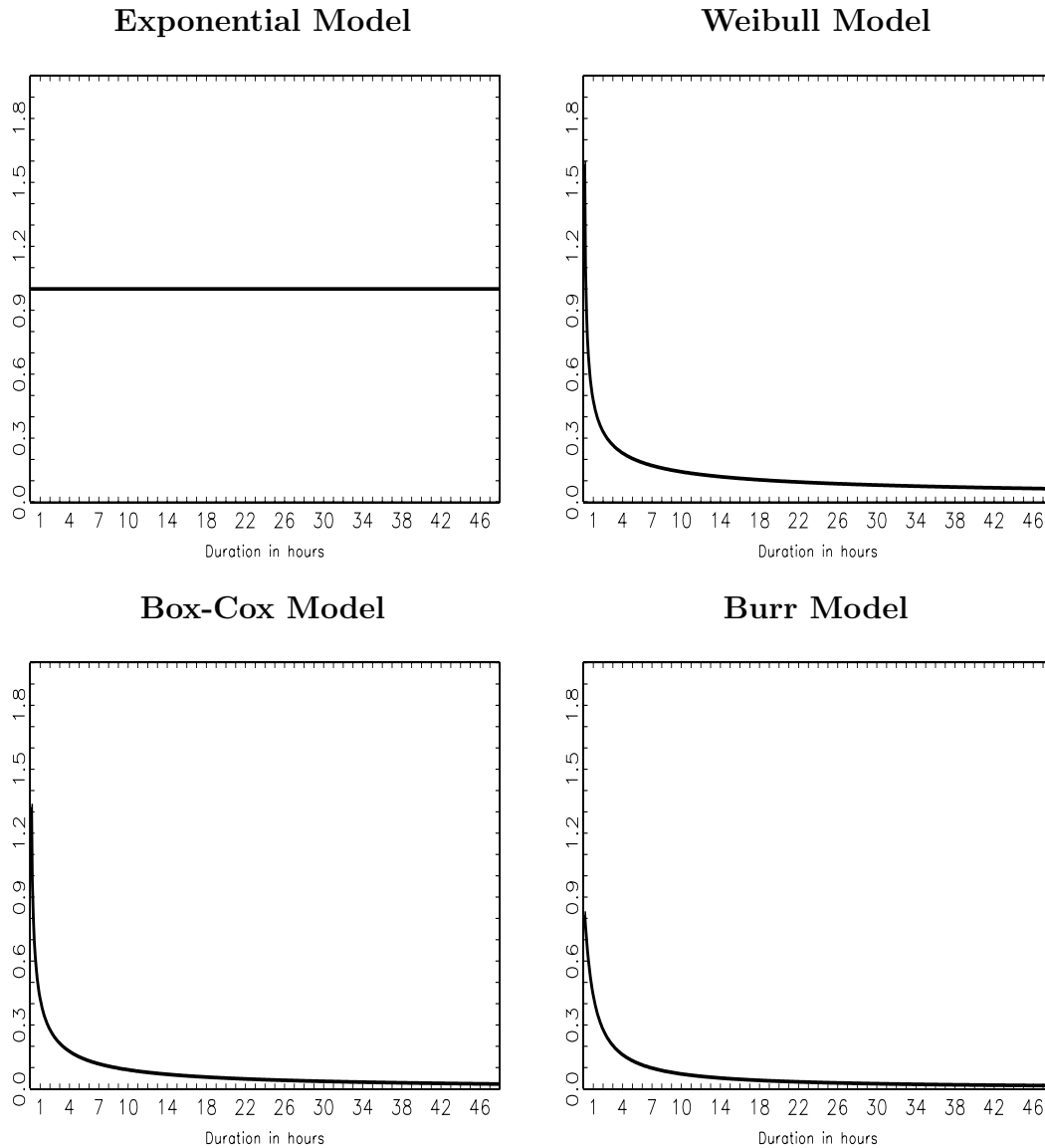


Figure 2: Baseline (unconditional) hazards of our four model specifications.

Let us now turn again to Table 3 to have a look at the signs of the explanatory variables which influence the duration of a roundtrip. In Table 11 in Appendix B we report the estimation results for the other currency pairs. There we state only the results of the Burr- model estimations, which turned out to provide the best fit also for these currency pairs. We therefore concentrate on the interpretation of the explanatory variables in these Burr- specifications. For all five currency pairs all covariates' coefficients (insignificant excluded) have the same sign. For the GBP/USD and the AUD/USD the coefficient on the maximum absolute volume invested per roundtrip (γ_{vo}) has a significantly positive sign, whereas for the remaining currency pairs it appears to have a non significant influence. This can be interpreted as a

tendency that roundtrip durations which involve a higher volume are shorter. This might be an indication for the fact that these roundtrips are better supervised by the investor and profits or losses are realized faster. For all five currency pairs, we find clearly significant negative signs for the influence of the previous roundtrip duration (γ_{s1}) and the previous inactivity duration (γ_{s2}), i.e. the higher the previous durations, the smaller the current hazard (the higher the current duration). This can be interpreted as a kind of habit persistence, which means that the trading horizon differs among traders. These observations yield a clear rejection of hypotheses H1.2. Furthermore, a similar picture can be found for the complexity of the trading strategy dummy (γ_{do}), whose coefficients are again for all five currency pairs highly significant and negative. This simply accounts for the fact that a more complex trading strategy takes a longer time. Except for the GBP/CHF currency pair (insignificant) γ_{do} and γ_{dc} have significant negative signs, which means that roundtrips which are either opened or/and closed by a limit order are longer. This effect is expected for roundtrips which are closed by a limit order, since in the case of new information, traders would submit a market order which would close the position immediately. However, the fact that we observe the same sign for roundtrips which are induced with a limit order is a little bit puzzling. It might be related to the risk preferences or the degree of patience of a group of traders. In our sample there might be traders whose preferences are so that they want to avoid price risk instead of time risk. Such a trader might want open a position at a certain, according to his preferences, predetermined price which would be the limit of his submitted opening limit order. Such a trader might want to wait until there is a good opportunity (price) to close the position again. If we assume that such a trader type (very patient, price risk avoider, uninformed) exists in our sample, the significantly negative sign of γ_{do} can be explained. A further puzzling significant positive sign (except for USD/CHF) is that of γ_{ds} , which states that positions in which the base currency is sold have a shorter duration. Since this can only hardly be related to long term decisions (median roundtrip duration between 0.4 to 5 hours), there is economically no interpretation for this effect. For the EUR/USD and the AUD/USD currency pairs, we find a difference between the durations of EUR account traders and non EUR account (mainly USD account, only 1% of all accounts are not managed in EUR or USD) since (γ_{da}) is significantly positive. This is the tendency that EUR account traders have shorter roundtrip durations. This effect needs further investigation, but it may be related to different sources and timing of information or risk attitudes.

All these significant influences account for (observable) different trading characteristics of our investors. Furthermore, the highly significant σ^2 in the Burr model suggests that there is unobserved heterogeneity among traders and yields a rejection of hypothesis H1.1. Since, hypotheses H1.1 to H1.3 can be clearly rejected for all five currency pairs, the proposed model set-up becomes indispensable and we can now proceed to investigate the disposition effect. So far, we spared the interpretation of γ_{pl} , whose significant negative sign for the EUR/USD, GBP/USD and the USD/CHF currency pairs support the results of the descriptive analysis. We do not find evidence of a general disposition effect, in the sense of Definition 1, even after controlling for several observable and unobservable trader characteristics.

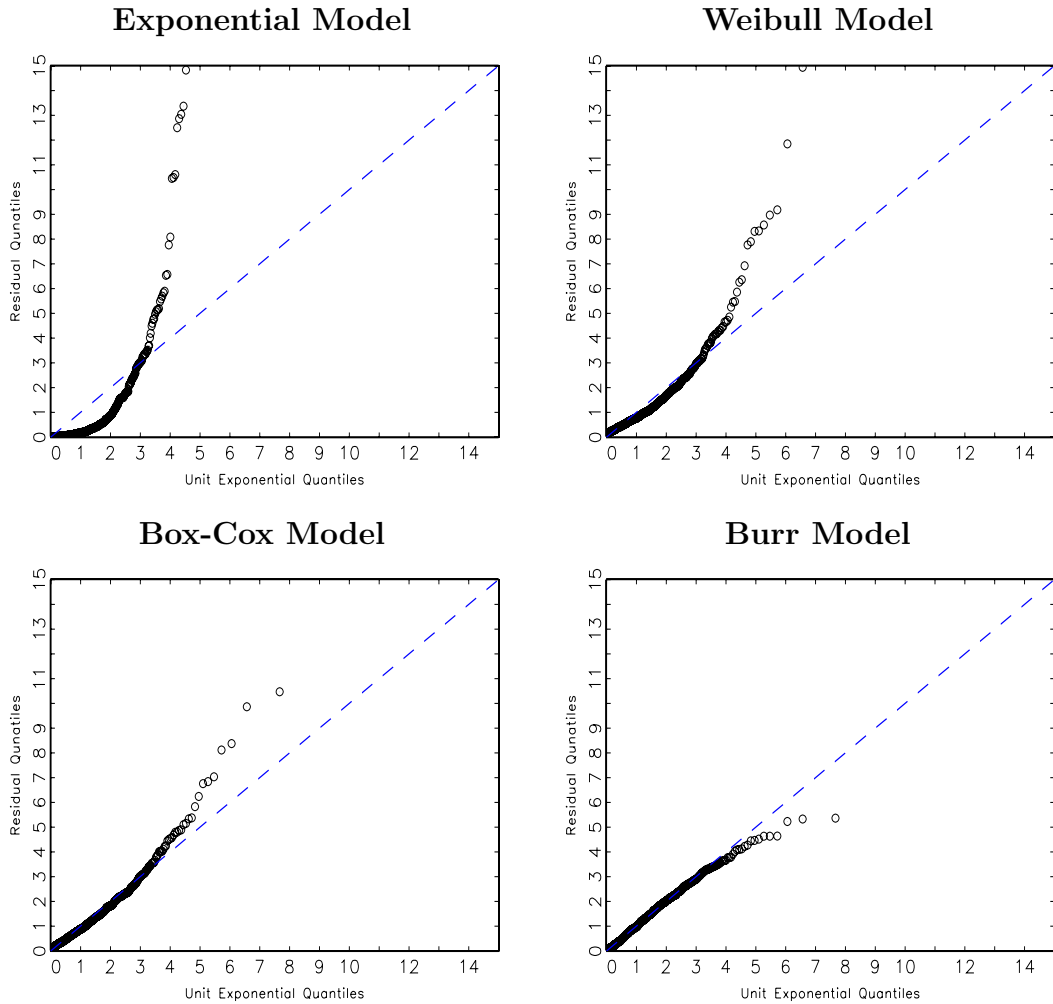


Figure 3: QQ-Plots of the pooled (over individuals and cycles) estimated integrated hazards of our four model specifications for the roundtrip state.

Specification with Interaction Terms (Hypotheses H2.1 to H3.2)

We now report on the estimation results, where the explanatory variables are chosen according to the augmented specification in equation (15). The results are given in Table 4 for the EUR/USD currency pair and in Tables 12 to 15 in Appendix B for the remaining 4 currency pairs. As mentioned before, the augmented specification is chosen to get a detailed picture of i) how the disposition effect changes with the size of the profit or loss (hypotheses H2.1 and H2.2), ii) how this change is related to overconfident investors (hypotheses H3, H3.1 and H3.2) and iii) how these effects differ for roundtrips which are closed with special limit orders (hypothesis H2.3).

Before we address these questions and the hypotheses in detail let us have a look at the general quality of the augmented set-up. The likelihood-ratio test statistic reports on the test of the plain specification (equation (12)) against the augmented specification (equation (15)). For all five considered currency pairs the null hypothesis can be clearly rejected, so that the explanatory power of the augmented specification can be considered as significantly higher. In the augmented specification, all explanatory variables which are not related to the profit or loss over the roundtrip keep exactly the same sign as in the plain specification for all five currency pairs, which shows to some extent the robustness of the found coefficients.

State	Parameter	Burr Model	State	Parameter	Burr Model	
State 1 (Round-trip)	c_1	-1.973 (.2460)	State 2 (Inactivity)	γ_{lodoc}	0.042 (.0102)	
	γ_{dpr}	0.960 (.0774)		γ_{lodsl}	-0.111 (.0179)	
	γ_{dprdsm}	0.214 (.0968)		γ_{pr^2}	0.019 (.0047)	
	γ_{dprdbi}	0.136 (.1058)		γ_{lo^2}	-0.005 (.0038)	
	γ_{dprdoc}	0.161 (.0305)		γ_{vo}	0.413 (.0273)	
	γ_{dprdsl}	-0.107 (.0915)		γ_{s1}	-0.299 (.0076)	
	γ_{dlo}	1.459 (.0744)		γ_{s2}	-0.088 (.0039)	
	γ_{dlodsm}	0.334 (.1159)		γ_{dco}	-1.531 (.0337)	
	γ_{dlodbi}	-0.044 (.0954)		γ_{do}	-0.184 (.0341)	
	γ_{dlodoc}	-0.120 (.0331)		γ_{dc}	-0.333 (.0787)	
	γ_{dlodsl}	-0.131 (.0943)		γ_{ds}	0.034 (.0120)	
	γ_{pr}	-0.915 (.0461)		γ_{da}	0.138 (.0460)	
	γ_{prdsm}	-1.391 (.0799)		α_1	1.083 (.0161)	
	γ_{prdbi}	0.158 (.0274)		σ^2	1.218 (.0364)	
	γ_{prdoc}	-0.042 (.0106)		State 3	c_3	-6.473 (.0491)
	γ_{prdsl}	-0.014 (.0168)		State 4	c_4	-6.896 (.0222)
	γ_{lo}	0.863 (.0345)				
γ_{lodsm}	1.296 (.0798)					
γ_{lodbi}	-0.210 (.0231)					
Observations	641230					
Mean log-likelih.	-1.72213					
LR-test	57005 (.0000)					
Residual Analysis						
Joint:			State 1:			
Mean ($\hat{\epsilon}_j$)	0.0000		Mean ($\hat{\epsilon}_i^1$)	-0.1591		
Variance ($\hat{\epsilon}_j$)	0.8814		Variance ($\hat{\epsilon}_i^1$)	0.2410		
Mean ($\hat{\epsilon}_i$)	-0.3320		State 2:			
Variance ($\hat{\epsilon}_i$)	0.2364		Mean ($\hat{\epsilon}_j^2$)	-0.0014		
State 1:			Variance ($\hat{\epsilon}_j^2$)	0.8283		
Mean ($\hat{\epsilon}_j^1$)	0.0014		Mean ($\hat{\epsilon}_i^2$)	-0.5400		
Variance ($\hat{\epsilon}_j^1$)	0.9340		Variance ($\hat{\epsilon}_i^2$)	0.6326		

Table 4: Estimation Results of the augmented Burr Model for the EUR/USD currency pair. Values in parenthesis () report the corresponding standard deviation. **Bold** numbers denote coefficients, which are not significant on the 5% level.

Let us now investigate the hypotheses proposed in Section 2. The estimated influence of a certain profit or loss $pl \in \mathbb{R}$ on the hazard function conditional on the further explanatory variables x^{1rest} and conditional on a certain duration s of the roundtrip, is represented by the following equation :

$$\hat{\theta}^1(pl|x^{1rest}, s) \equiv \hat{\theta}^1(pl|x^{1rest}, s; \hat{\gamma}^{1pl}, \hat{\gamma}^{1rest}, \hat{\sigma}, \hat{\alpha}_1) = \frac{\exp(\hat{\gamma}^{1pl}x^{1pl}) \exp(\hat{\gamma}^{1rest}x^{1rest}) \hat{\alpha}_1 s^{\hat{\alpha}_1-1}}{1 + \hat{\sigma}^2 \exp(\hat{\gamma}^{1pl}x^{1pl}) \exp(\hat{\gamma}^{1rest}x^{1rest}) s^{\hat{\alpha}_1}} \quad (18)$$

where

$$pr \equiv \begin{cases} pl & \text{if } pl > 0 \\ 0 & \text{otherwise,} \end{cases}$$

and

$$lo \equiv \begin{cases} pl & \text{if } pl < 0 \\ 0 & \text{otherwise,} \end{cases}$$

and

$$\begin{aligned} \hat{\gamma}^{1pl}x^{1pl} &= \hat{c}_1 \\ &+ \hat{\gamma}_{dpr}dpr + \hat{\gamma}_{dprdsm}dprdsm + \hat{\gamma}_{dprdbi}dprdbi + \hat{\gamma}_{dprdloc}dprdloc + \hat{\gamma}_{dprdsl}dprdsl \\ &+ \hat{\gamma}_{dlo}dlo + \hat{\gamma}_{dlodsm}dlodsm + \hat{\gamma}_{dlodbi}dlodbi + \hat{\gamma}_{dlodoc}dlodoc + \hat{\gamma}_{dlodsl}dlodsl \\ &+ \hat{\gamma}_{pr}pr + \hat{\gamma}_{prdsm}prisdsm + \hat{\gamma}_{prdbi}prdbi + \hat{\gamma}_{prdloc}prdloc + \hat{\gamma}_{prdsl}prdsl \\ &+ \hat{\gamma}_{lo}lo + \hat{\gamma}_{lodsm}loisdsm + \hat{\gamma}_{lodbi}lodbi + \hat{\gamma}_{lodoc}lodoc + \hat{\gamma}_{lodsl}lodsl \\ &+ \hat{\gamma}_{pr^2}pr^2 + \hat{\gamma}_{lo^2}lo^2. \end{aligned}$$

Equation (18) is simply the fitted Burr-hazard with respect to profits and losses given the further explanatory variables and it gives a detailed insight into how a certain profit or loss affects the hazard function and therefore the probability of leaving the roundtrip state.

With the help of equation (18) we can now address the hypotheses. According to Definition 1, there is no disposition effect at all if the function described by equation (18) is axially symmetric, which can be translated into

$$\hat{D}(pl|x^{1rest}, s) \equiv \hat{\theta}^1(pl|pl > 0; x^{1rest}, s) - \hat{\theta}^1(pl|pl < 0; x^{1rest}, s) \quad (19)$$

being equal to zero for all profit and loss sizes. In this case the probability to leave the roundtrip state would be exactly the same for a $x > 0$ units-of-the-base-currency-loss than for a $x > 0$ units-of-the-base-currency-profit. In the first panel in Figure 4

we plotted the following three functions:

$$\hat{D}(pl|doc = 0, dsl = 0, dsm = 0, dbi = 0; x^{1rest} = \bar{x}^{1rest}, s = s_{0.5}) \quad (20)$$

$$\hat{D}(pl|doc = 1, dsl = 0, dsm = 0, dbi = 0; x^{1rest} = \bar{x}^{1rest}, s = s_{0.5}) \quad (21)$$

$$\hat{D}(pl|doc = 0, dsl = 1, dsm = 0, dbi = 0; x^{1rest} = \bar{x}^{1rest}, s = s_{0.5}) \quad (22)$$

for the EUR/USD currency pair, where we choose the further explanatory variables x^{1rest} to be equal to their sample means \bar{x}^{1rest} and the duration of a roundtrip s to be equal to its median (compare Tables 2, 9 and 10). Function (20) is represented by the solid black line. This is the general picture of the disposition effect for all investors under consideration. The case, where there would be no disposition effect at all would correspond to the curve being equal to the zero line. The short dashed blue line represents equation (21) and shows the disposition effect for all investors that are overconfident measured by past trading success. The dashed red line represents the last equation (22) and depicts the disposition effect for all investors that close their roundtrip with a special limit order. In the second and third panel in Figure 4 we plotted the corresponding three functions for small/not general overconfident ($dsm = 1$) and big/general overconfident ($dbi = 1$) investors again, focusing on overconfidence measured with respect to the trading volume.

In the second column of Table 5 we report for all five currency pairs a likelihood ratio test statistic ($LR_{(dispo)}$) where we test whether the shape of the disposition effect for all investors (solid black line) is significantly different from being equal to zero. Since the Burr model is a proportional mixture of a Weibull model and a Gamma variate (compare equation (8)) it turns out that the test for $D(pl|doc = 0, dsl = 0, dsm = 0, dbi = 0; x^{1rest} = \bar{x}^{1rest}, s = s_{0.5}) = 0$ (axial symmetry of $\theta^1(pl|x^{1rest}, s)$) simply coincides with the following parameter test:

$$\gamma_{dpr} = \gamma_{dlo}, \quad \gamma_{pr} = -\gamma_{lo}, \quad \gamma_{pr^2} = \gamma_{lo^2}$$

For all five currency pairs the null hypothesis of an axially symmetric specification can be clearly rejected, which provides evidence for the shape of the disposition effect. In Figure 5 we plotted for the remaining 4 currency pairs the shape of the disposition effect for all investors. These figures correspond to the first panel in Figure 4. In Figure 6 and Figure 7 we depict the same information for small and big investors, which corresponds to the second and third panel of Figure 4. We can derive the following results:

For the profit and loss region where a plotted curve lies above the zero line, we find evidence for the disposition effect, since the value of the curve at a specific point

(size of the profit or loss) represents how much it is more likely that one leaves the roundtrip state in case of a profit than in case of a loss. Whenever a plotted curve is below the zero line we observe an inverse disposition effect. We find clear evidence that the size (here quantified in terms of probabilities) of the disposition effect changes with the size of the profit or loss, which clearly supports hypothesis H2.1.

Moreover, a very robust finding is that for all investors there is an inverse disposition effect for small profits and losses, and that after exceeding a certain threshold, evidence for the usual disposition effect can be found. For the EUR/USD currency pair this threshold lies at around 250 EUR (Figure 4, first panel, solid black line) for the chosen specification (further explanatory variables set to their mean, roundtrip duration set to its median). Since we consider a mixed proportional hazard model, the inverse disposition effect region, the threshold, and the disposition effect region changes with the choice of the values for the conditioning variables. However, the general patterns are always kept and the effects vary only in their size. This observation clearly supports hypothesis H2.2.

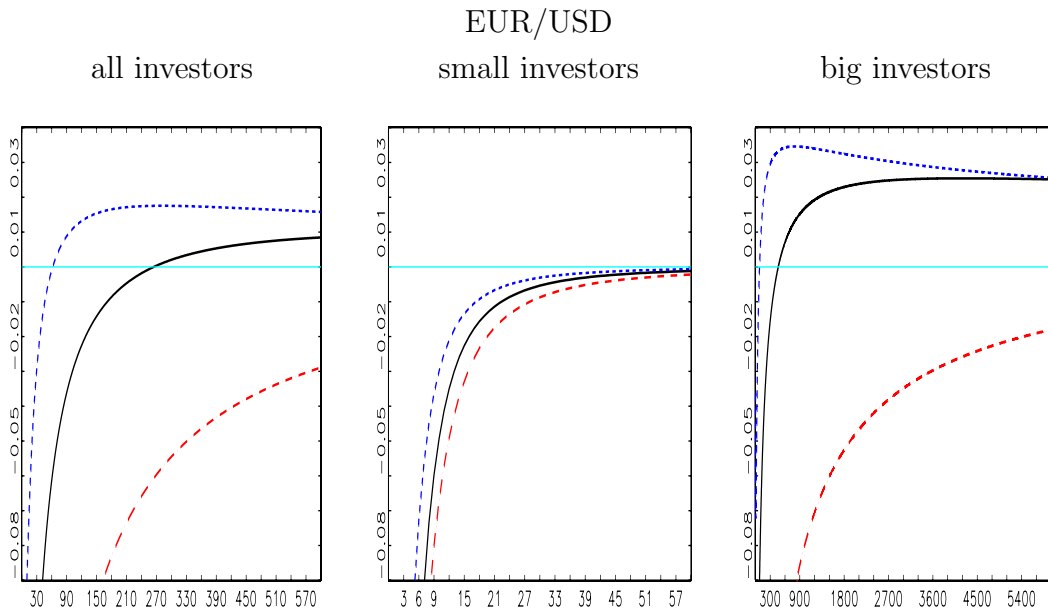


Figure 4: Shape of the disposition effect for the EUR/USD currency pair. The number at the x-axis represent the size of a profit or loss. The numbers on the y-axis represent how more likely it is that one leaves the roundtrip state in case of a profit than in case of a loss. The solid black line represents in the first (second, third) panel the effect for all (small/not general overconfident, big/general overconfident) investors. The short dashed blue line is drawn for temporary overconfident (past investment success) investors and the dashed red line is drawn for round trips being completed with a special limit order (stop loss, take profit).

A further very robust result is that the short dashed blue curve is always above the solid black one, whereas the dashed red curve is always below.

The dashed red curve lying below shows that the inverse disposition effect is much more pronounced for roundtrips which are closed by special limit orders. The likelihood ratio test statistics ($LR_{(sl)}$) in Table 5 shows that this effect is highly significant for all five currency pairs, which clearly supports hypothesis H2.3.

Let us now turn to verify hypotheses H3, H3.1 and H3.2. The short dashed blue curve lying above states that the disposition effect is even more pronounced (the inverse disposition effect region becomes smaller) for investors which are temporary overconfident due to their performance during the last two roundtrips (self attribution bias). The likelihood ratio test statistics ($LR_{(oc)}$) in Table 5 shows that this effect is highly significant for all five currency pairs as well, which clearly supports hypothesis H3.1. This states that the inverse disposition effect for small profits and losses is driven to a certain degree by the submission of take profit and stop loss orders, where roundtrips which end with a stop loss order are shorter than the corresponding roundtrips, which end with a take profit order.

When we consider the curves in the second panel in Figure 4 as well as the graphs in Figure 6, we see that small/not general overconfident investors do not exhibit the disposition effect, even if they are temporary overconfident (past trading success). None of the curves ever crosses the zero line. The effect of special limit orders completing a roundtrip can be found here as well. In contrast thereto, big/generally overconfident investors (third panel in Figure 4 and Figure 6), are more subject to the disposition effect. The effect of temporary overconfidence (short dashed blue line) however seems to be not that severe. The special limit order effect can be found again. The likelihood ratio test statistics ($LR_{(sm)}$) and ($LR_{(bi)}$) in Table 5 report on the significance whether the shape of the disposition effect is different for small and big investors in comparison to all investors. Once again, we find that the observed effects are highly significant. Thus, we find also clear evidence for hypothesis H3.2. Since, hypothesis H3.1 is already confirmed we can claim that overconfident investors exhibit a more pronounced disposition effect than investors being not overconfident, which supports hypothesis H3.

	$LR_{(dispo)}$	$LR_{(oc)}$	$LR_{(sl)}$	$LR_{(sm)}$	$LR_{(bi)}$
Restrictions	$\gamma_{dpr} = \gamma_{dlo}$ $\gamma_{pr} = -\gamma_{lo}$ $\gamma_{pr^2} = \gamma_{lo^2}$	$\gamma_{dprdoc} = 0$ $\gamma_{prdoc} = 0$ $\gamma_{dlodoc} = 0$ $\gamma_{lodoc} = 0$	$\gamma_{dprdsl} = 0$ $\gamma_{prdsl} = 0$ $\gamma_{dlodsl} = 0$ $\gamma_{lodsl} = 0$	$\gamma_{dprdsm} = 0$ $\gamma_{prdsm} = 0$ $\gamma_{dlodsm} = 0$ $\gamma_{lodsm} = 0$	$\gamma_{dprdbi} = 0$ $\gamma_{prdbi} = 0$ $\gamma_{dlodbi} = 0$ $\gamma_{lodbi} = 0$
EUR/USD	5643 (.0000)	500.1 (.0000)	666.8 (.0000)	6630 (.0000)	3526 (.0000)
GBP/USD	444.6 (.0000)	76.14 (.0000)	130.1 (.0000)	1333 (.0000)	304.5 (.0000)
AUD/USD	178.2 (.0000)	65.46 (.0000)	72.73 (.0000)	923.7 (.0000)	287.3 (.0000)
USD/CHF	457.8 (.0000)	88.49 (.0000)	188.9 (.0000)	1181 (.0000)	359.1 (.0000)
GBP/CHF	17.24 (.0006)	15.75 (.0033)	120.4 (.0000)	100.8 (.0000)	8.939 (.0626)

Table 5: Likelihood ratio test statistics: $LR_{(dispo)}$ reports on the test whether there is a disposition effect at all. $LR_{(oc)}$, $LR_{(sm)}$ and $LR_{(bi)}$ report on the tests whether the disposition effect for temporary overconfident, not general overconfident (small) and general overconfident (big) investors takes a different form. $LR_{(sl)}$ reports on the test whether the disposition effect takes a different form for roundtrips which are closed by special limit orders.

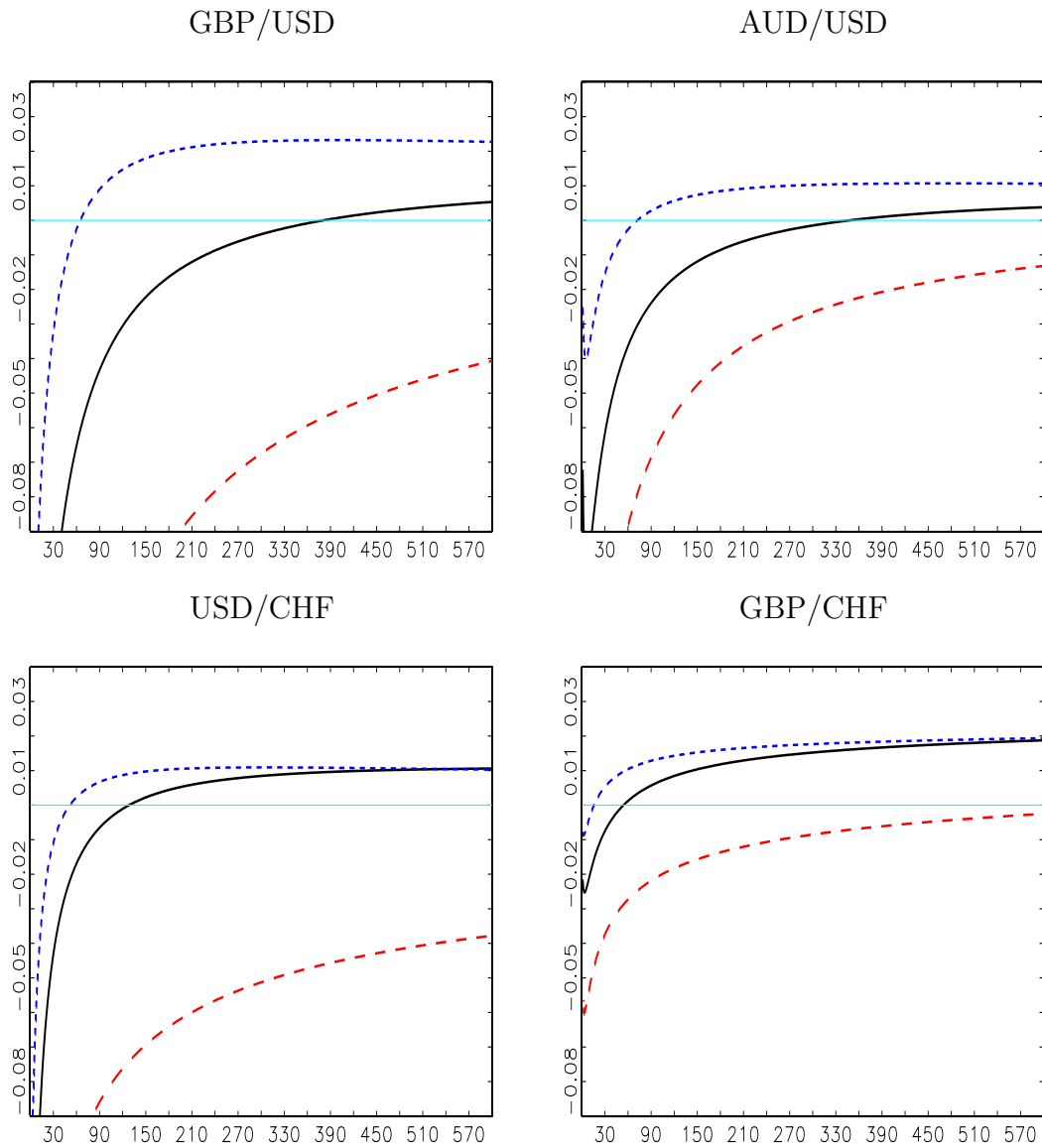


Figure 5: Shape of the disposition effect for the remaining currency pair for all investors. The number at the x-axis represent the size of a profit or loss. The numbers on the y-axis represent how more likely it is that one leaves the roundtrip state in case of a profit than in case of a loss. The solid black line represents the effect for all investors. The short dashed blue line is drawn for temporary overconfident investors and the dashed red line is drawn for round trips being completed with a special limit order (stop loss, take profit).

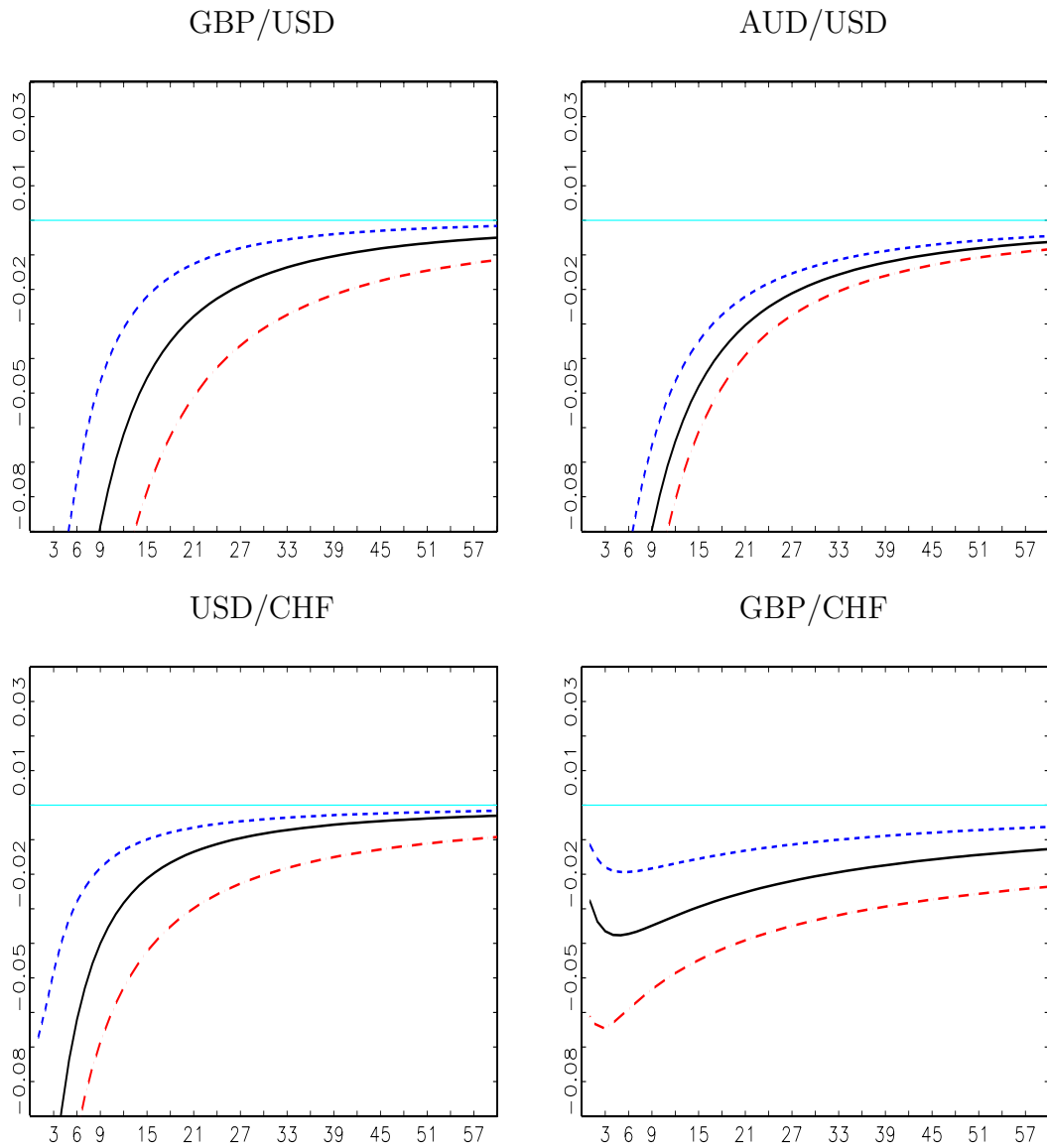


Figure 6: Shape of the disposition effect for the remaining currency pair for small investors. The number at the x-axis represent the size of a profit or loss. The numbers on the y-axis represent how more likely it is that one leaves the roundtrip state in case of a profit than in case of a loss. The solid black line represents the effect for small and not general overconfident investors. The short dashed blue line is drawn for temporary overconfident investors and the dashed red line is drawn for round trips being completed with a special limit order (stop loss, take profit).

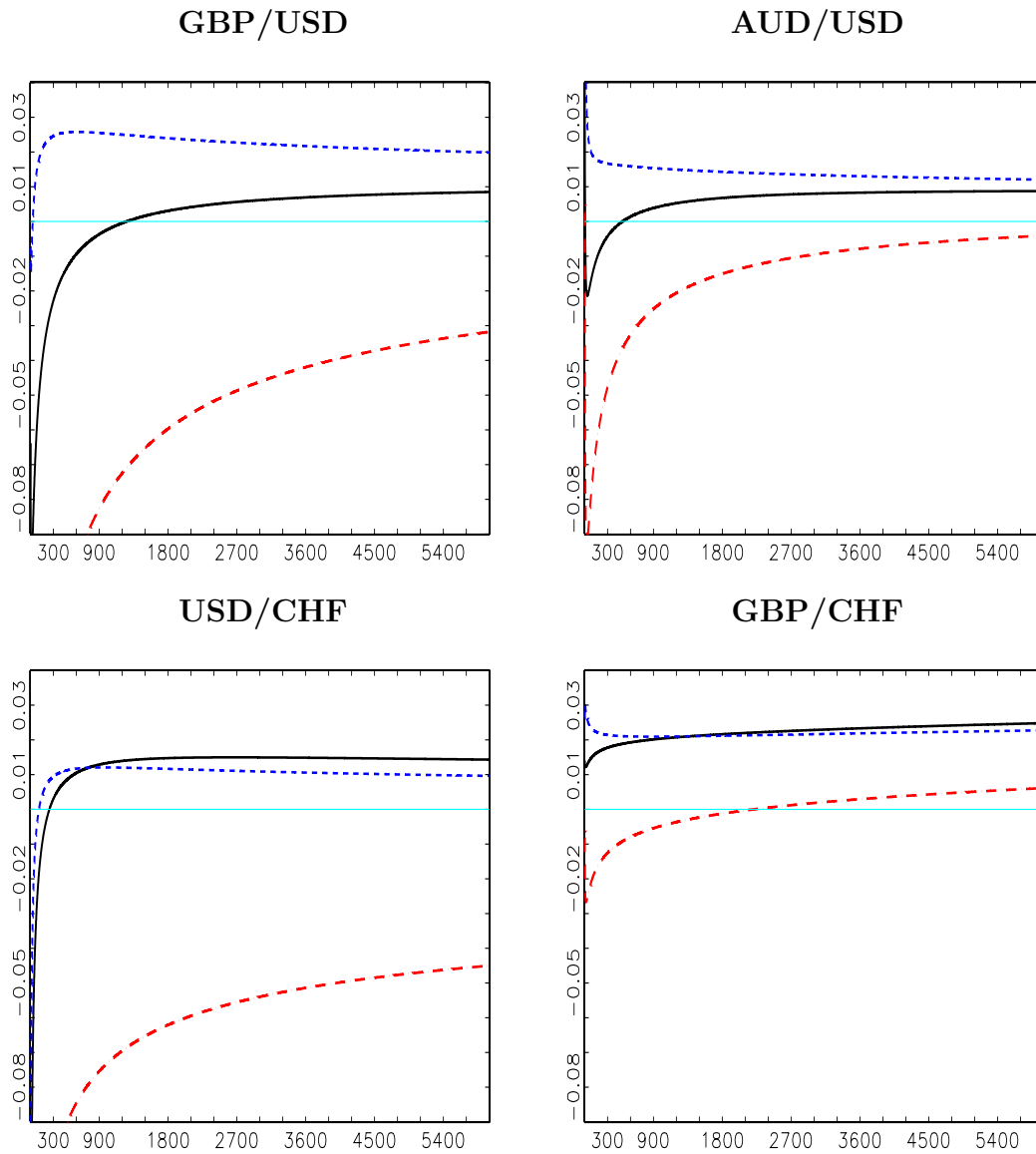


Figure 7: Shape of the disposition effect for the remaining currency pair for big investors. The number at the x-axis represent the size of a profit or loss. The numbers on the y-axis represent how more likely it is that one leaves the roundtrip state in case of a profit than in case of a loss. The solid black line represents the effect for big and overconfident investors. The short dashed blue line is drawn for temporary overconfident investors and the dashed red line is drawn for round trips being completed with a special limit order (stop loss, take profit).

6 Conclusion

This paper investigates trading behavior of retail foreign exchange market traders. The data-set underlying this study allows us to trace individual trading behavior on OANDA FXTrade over time. Thereby, trading events occur typically irregular in time. We propose a panel duration setting to characterize the trading behavior of these individuals. The panel duration models enable us to extract the most fundamental form of market microstructure information on the timing of trades. We concentrate on the modelling of roundtrip and inactivity durations, where roundtrip durations are defined as the elapsed time from entering into an investment in a currency pair until leaving it, and inactivity durations are defined as the time between two roundtrips. Several explanatory variables are computed for roundtrip durations, which make it possible to distinguish between individual trading preferences. We propose proportional and mixed proportional hazard models, where the latter ones permit us to control, in addition to observable differences, for unobserved heterogeneity among traders.

We apply our model set-up first, to investigate the trading behavior of retail investors and second, to analyze the disposition effect in detail. The disposition effect, the tendency to sell assets which gained in value earlier than assets with corresponding losses, is a well known and often studied behavioral bias in the behavioral finance literature. Our panel data duration models allow us to investigate the disposition effect conditional on trading characteristics in a rigorous econometric framework, since i) the time on which the disposition depends is explicitly modelled, ii) the panel structure of the underlying data-set is exploited and iii) unobservable heterogeneity is taken into account. In comparison to studies, which analyze the trading behavior of discount broker traders the obtained results are more accurate, since the set of possible trading instruments is highly limited and investments in the same trading instruments (currency pair) are traced over time.

Our main findings are that: i) There is no general disposition effect, in the sense that the probability of leaving the roundtrip state is for any $x > 0$ units-of-the-base currency loss lower than the corresponding probability of a $x > 0$ units-of-the-base currency profit. ii) Instead, we find that up to a certain threshold the probability of leaving the roundtrip state is, in case of a loss, higher than in case of the corresponding profit (inverse disposition effect). From that threshold onward,

the usual disposition effect can be found. iii) The inverse disposition effect is more pronounced when roundtrips are closed by special limit orders. iv) Traders which are generally overconfident and those which are temporary overconfident (self attribution biased) when they complete a roundtrip, exhibit a more pronounced disposition effect. These main findings are very robust since each of these results is valid for each of the five currencies under investigation.

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Appendix A

Buy/Sell market* open (close)	Immediately executed to open or close a position in a specific currency pair.
Buy/Sell limit order	The trader posted a buy or sell limit order to the system, which is then pending.
Buy/Sell limit order executed open (close)	Pending limit order is executed to open or close a certain position.
Buy/Sell take-profit close	Closes an open position by buying or selling the currency pair when the exchange rate reaches a predetermined level, in order to make a profit.
Buy/Sell stop-loss close	Closes an open position by buying or selling the currency pair when the exchange rate reaches a predetermined level in order to avoid further losses.
Buy/Sell margin call close	Closes automatically all open positions using the prevalent market rates at the closing time. This happens if the trader has not sufficient margin to cover two times the losses of all open positions.
Change order	Change of a pending limit order (limits for take-profit or stop-loss, the value of the upper or lower bounds, the quote as well as the number of units).
Change stop-loss or take profit on open trade	Change stop-loss or take-profit limit on an open position.
Cancel order by hand	Cancel a pending limit order by hand.
Cancel order: insufficient funds	Automatically recorded when the trader has not enough funds to open a new position.
Cancel order: bound violation	Market order or limit order is cancelled because the applied exchange rate is not located inside the specified bounds.
Order expired	A pending limit order is expired.

Table 6: Activity record entries of OANDA FXTrade.

*On the OANDA FXTrade platform, buying *EUR/USD* means that you are buying the base currency (*EUR*) and selling the quote currency (*USD*), whereas selling *EUR/USD* means that you are selling the base currency (*EUR*) and buying the quote currency (*USD*). Recorded units always refer to the base currency.

Appendix B

GBP/USD	durations in hours			
	roundtrip	inactivity	cens. roundtrip	cens. inactivity
observations	61199	59501	285	1834
mean	15.472	54.848	558.39	1218.0
std. deviation	88.186	219.99	792.96	1320.1
skewness	18.119	9.5658	1.9343	1.2140
kurtosis	486.05	126.81	7.7408	3.7399
minimum	0.0003	0.0003	7.2700	2.0525
1% Quantile	0.0075	0.0025	7.3174	11.845
5% Quantile	0.0247	0.0078	11.671	14.813
10% Quantile	0.0469	0.0181	13.549	21.081
25% Quantile	0.1533	0.1175	20.013	106.03
50% Quantile	0.6801	1.7138	181.24	716.62
75% Quantile	4.0646	21.573	765.02	1933.5
90% Quantile	21.901	113.88	1909.7	3105.9
95% Quantile	64.465	231.98	2085.2	4143.8
99% Quantile	286.55	1001.0	2981.2	5124.4
maximum	4031.2	5040.2	5272.2	5438.1
AUD/USD	durations in hours			
	roundtrip	inactivity	cens. roundtrip	cens. inactivity
observations	45248	43980	277	1419
mean	21.392	57.350	533.58	1308.2
std. deviation	104.22	222.58	859.65	1325.8
skewness	15.021	9.2163	2.7442	1.1154
kurtosis	338.84	118.66	12.337	3.5326
minimum	0.0003	0.0003	1.4022	1.8597
1% Quantile	0.0086	0.0028	6.2136	9.4161
5% Quantile	0.0311	0.0075	11.092	14.122
10% Quantile	0.0631	0.0175	14.085	25.321
25% Quantile	0.2156	0.1200	35.361	126.12
50% Quantile	1.0664	1.8831	182.69	936.96
75% Quantile	7.2800	21.646	625.51	2027.4
90% Quantile	37.994	119.63	2034.7	3295.1
95% Quantile	95.069	261.70	2095.7	4270.9
99% Quantile	342.15	1009.3	4390.9	5127.3
maximum	4437.4	5178.9	5387.6	5404.3

Table 7: Descriptive statistics of the durations per state for the GBP/USD (upper table) and the AUD/USD (lower table) currency pairs. The sample ranges from 1st October 2003 00:00:00 (EST) to 14th May 2004 23:59:59 (EST), which are 227 full days (5448 hours).

USD/CHF	durations in hours			
	roundtrip	inactivity	cens. roundtrip	cens. inactivity
observations	42331	40925	260	1575
mean	21.629	68.318	807.12	1381.0
std. deviation	116.48	246.88	1240.4	1401.3
skewness	15.399	8.5095	2.0189	0.9435
kurtosis	328.74	102.22	5.9347	2.8265
minimum	0.0003	0.0003	6.1308	3.6594
1% Quantile	0.0089	0.0019	9.3594	12.200
5% Quantile	0.0361	0.0072	11.830	15.250
10% Quantile	0.0756	0.0181	14.112	35.249
25% Quantile	0.2550	0.1633	36.077	183.48
50% Quantile	1.1436	3.0711	396.04	908.69
75% Quantile	6.7584	28.966	583.73	2256.0
90% Quantile	32.928	142.31	2933.3	3658.5
95% Quantile	84.923	317.06	4418.5	4260.9
99% Quantile	376.02	1178.8	4565.0	5103.5
maximum	3747.1	4851.9	4597.0	5418.1
GBP/CHF	durations in hours			
	roundtrip	inactivity	cens. roundtrip	cens. inactivity
observations	5264	4814	75	489
mean	50.104	147.89	659.10	1696.6
std. deviation	177.31	398.15	967.47	1441.8
skewness	8.0705	4.9416	2.3439	0.7465
kurtosis	87.229	33.455	9.1783	2.4482
minimum	0.0011	0.0003	8.6253	6.9908
1% Quantile	0.0152	0.0023	8.7713	12.006
5% Quantile	0.0956	0.0092	10.579	49.413
10% Quantile	0.2272	0.0413	12.469	101.18
25% Quantile	0.9397	0.9739	27.232	446.25
50% Quantile	5.2789	14.955	313.75	1381.0
75% Quantile	22.692	95.935	740.47	2616.6
90% Quantile	104.76	361.22	1764.9	4050.5
95% Quantile	212.83	827.06	2070.9	4469.3
99% Quantile	820.53	2067.6	3999.2	5092.8
maximum	3047.8	4179.3	5141.3	5282.9

Table 8: Descriptive statistics of the durations per state for the USD/CHF (upper table) and the GBP/CHF (lower table) currency pairs. The sample ranges from 1st October 2003 00:00:00 (EST) to 14th May 2004 23:59:59 (EST), which are 227 full days (5448 hours).

GBP/USD # investors: 2119	profit & loss	volume in base ccy	durations in hours			dummy variable	mean
			loss	zero- profit	profit		
observations	61199	61199	35339	1638	24222	complex strategy	0.2018
mean	37.96	28395.10	14.992	2.6129	17.043	opening limit order	0.1435
std. deviation	6021	227006.4	84.376	14.119	96.099	closing limit order	0.3697
skewness	152.14	72.3264	21.076	16.183	14.529	short in base ccy	0.4599
kurtosis	25098	6982.985	657.06	386.05	300.62	account in EUR	0.0949
minimum	-114027	1	0.0011	0.0014	0.0003	small investor	0.3034
1% Quantile	-699.5	1	0.0111	0.0048	0.0047	big investor	0.0467
5% Quantile	-120	49	0.0308	0.0169	0.0183	overconfident investor	0.3727
10% Quantile	-37.60	120	0.0558	0.0306	0.0369	special limit order closing	0.3538
25% Quantile	-2.85	900	0.1803	0.0756	0.1311		
50% Quantile	0.2	4000	0.7947	0.2278	0.5886		
75% Quantile	6.5	17000	4.6913	0.8199	3.5036		
90% Quantile	45.51	50000	22.678	3.0569	21.861		
95% Quantile	125	100000	65.861	8.1484	66.101		
99% Quantile	693.01	310022.6	239.52	64.629	335.13		
maximum	1003300	25000000	4031.2	394.85	3701.8		
AUD/USD # investors: 1696	profit & loss	volume in base ccy	durations in hours			dummy variable	mean
observations	45248	45248	27154	1776	16318	complex strategy	0.2102
mean	-6.4917	70513.38	20.048	3.6583	25.559	opening limit order	0.1350
std. deviation	2430.2	401114.9	95.450	21.791	121.87	closing limit order	0.3638
skewness	-139.02	18.9394	16.536	17.787	12.751	short in base ccy	0.4328
kurtosis	26383	582.4327	436.49	421.74	227.99	account in EUR	0.0861
minimum	-451273	1	0.0006	0.0011	0.0003	small investor	0.2636
1% Quantile	-968.98	2	0.0108	0.0058	0.0058	big investor	0.0814
5% Quantile	-102.10	57.4	0.0361	0.0166	0.0264	overconfident investor	0.3955
10% Quantile	-30.4	200	0.0733	0.0308	0.0567	special limit order closing	0.3494
25% Quantile	-2	1000	0.2436	0.0800	0.2031		
50% Quantile	0.2800	5700	1.1628	0.2706	1.0853		
75% Quantile	6.4647	27000	7.4249	1.1278	8.3226		
90% Quantile	45	100000	37.511	5.0246	45.172		
95% Quantile	120	230000	92.070	12.782	115.72		
99% Quantile	981.18	1232080	317.87	63.185	449.99		
maximum	102322	23148202	4437.4	620.79	3377.5		

Table 9: Descriptive statistics of the explanatory variables for the GBP/USD (upper table) and the AUD/USD (lower table) currency pairs. The sample ranges from 1st October 2003 00:00:00 (EST) to 14th May 2004 23:59:59 (EST), which are 227 full days (5448 hours).

USD/CHF # investors: 1835	profit & loss	volume in base ccy	durations in hours			dummy variable	mean
			loss	zero- profit	profit		
observations	42331	42331	24370	1104	16857	complex strategy	0.2129
mean	144.612	52411.14	21.254	3.3533	23.368	opening limit order	0.1648
std. deviation	13630.9	627908.5	107.40	11.767	131.77	closing limit order	0.3855
skewness	113.416	67.5396	15.748	10.128	14.354	short in base ccy	0.4440
kurtosis	14017.4	5851.687	359.15	155.25	274.34	account in EUR	0.0970
minimum	-135950	1	0.0017	0.0014	0.0003	small investor	0.2845
1% Quantile	-727.948	1	0.0169	0.0083	0.0044	big investor	0.0616
5% Quantile	-120	20	0.0515	0.0234	0.0231	overconfident investor	0.3704
10% Quantile	-36.4270	100	0.0994	0.0457	0.0533	special limit order closing	0.3730
25% Quantile	-2.7	700	0.3107	0.1386	0.1975		
50% Quantile	0.15	3500	1.4003	0.4703	0.8936		
75% Quantile	6.3299	15772.5	8.0043	1.7653	5.4509		
90% Quantile	47.3585	60000	37.470	6.9597	31.289		
95% Quantile	136.5	120000	87.081	14.823	87.353		
99% Quantile	1015.6	736100	357.78	57.328	449.43		
maximum	1772500	60000000	3747.1	232.38	3654.2		
GBP/CHF # investors: 564	profit & loss	volume in base ccy	durations in hours			dummy variable	mean
			loss	zero- profit	profit		
observations	5264	5264	3493	60	1711	complex strategy	0.2477
mean	14.5326	18442.55	52.624	29.672	45.674	opening limit order	0.2717
std. deviation	774.046	131826.4	190.68	113.76	148.39	closing limit order	0.4818
skewness	19.8764	17.7926	8.1485	6.1828	6.8926	short in base ccy	0.3866
kurtosis	1225.66	398.8026	86.218	43.719	65.121	account in EUR	0.0922
minimum	-17379.8	1	0.0011	0.0186	0.0014	small investor	0.5053
1% Quantile	-633.44	1	0.0391	0.0196	0.0048	big investor	0.0213
5% Quantile	-59.204	6	0.1378	0.0500	0.0493	overconfident investor	0.5012
10% Quantile	-13.38	25	0.3067	0.1211	0.1291	special limit order closing	0.4158
25% Quantile	-0.404	150	1.2012	0.3117	0.5770		
50% Quantile	0.3	1000	5.5743	1.3364	4.5374		
75% Quantile	5.4825	4528	22.968	10.052	22.676		
90% Quantile	40.32	24000	108.91	38.703	95.699		
95% Quantile	133	50000	214.06	146.40	211.38		
99% Quantile	800	300000	861.53	455.98	720.08		
maximum	38100	4000000	3047.8	843.26	2144.6		

Table 10: Descriptive statistics of the explanatory variables for the USD/CHF (upper table) and the GBP/CHF (lower table) currency pairs. The sample ranges from 1st October 2003 00:00:00 (EST) to 14th May 2004 23:59:59 (EST), which are 227 full days (5448 hours).

State	Parameter	GBP/USD	AUD/USD	USD/CHF	GBP/CHF
State 1 (Round-trip)	c_1	0.439 (.1095)	-0.163 (.1172)	0.125 (.0934)	-0.821 (.1227)
	γ_{pl}	-0.025 (.0050)	0.002 (.0051)	-0.026 (.0050)	-0.005 (.0097)
	γ_{vo}	0.024 (.0094)	0.045 (.0098)	0.012 (.0098)	0.020 (.0112)
	γ_{s1}	-0.333 (.0099)	-0.318 (.0140)	-0.279 (.0102)	-0.236 (.0158)
	γ_{s2}	-0.082 (.0061)	-0.091 (.0081)	-0.065 (.0054)	-0.039 (.0100)
	γ_{dco}	-1.616 (.0498)	-1.464 (.0621)	-1.437 (.0629)	-1.278 (.0831)
	γ_{do}	-0.406 (.0532)	-0.235 (.0858)	-0.242 (.0482)	-0.046 (.0713)
	γ_{dc}	-0.387 (.0398)	-0.226 (.0442)	-0.241 (.0392)	0.129 (.0669)
	γ_{ds}	0.073 (.0206)	0.133 (.0248)	-0.040 (.0230)	0.091 (.0450)
	γ_{da}	0.143 (.0734)	0.282 (.1379)	0.114 (.0693)	0.025 (.1210)
	α_1	0.879 (.0208)	0.818 (.0238)	0.778 (.0185)	0.680 (.0216)
	σ^2	0.912 (.0477)	0.826 (.0578)	0.677 (.0401)	0.373 (.0412)
State 2 (Inactivity)	c_2	-0.300 (.0672)	-0.361 (.0848)	-0.584 (.0575)	-1.287 (.0816)
	α_2	0.496 (.0089)	0.480 (.0106)	0.451 (.0079)	0.430 (.0162)
State 3	c_3	-6.325 (.0840)	-6.279 (.0966)	-6.693 (.0951)	-6.490 (.1684)
State 4	c_4	-7.105 (.0253)	-7.176 (.0269)	-7.230 (.0256)	-7.436 (.0384)
Observations		122819	90924	85091	10642
Mean log-likelih.		-2.55772	-2.80753	-2.97883	-4.13520
Residual Analysis					
Joint:					
Mean ($\hat{\varepsilon}_j$)		0.0000	0.0000	0.0000	0.0000
Variance ($\hat{\varepsilon}_j$)		0.9198	0.9189	0.9511	0.9877
Mean ($\hat{\varepsilon}_i$)		-0.3197	-0.3517	-0.3009	-0.2031
Variance ($\hat{\varepsilon}_i$)		0.2731	0.2453	0.2620	0.2929
State 1:					
Mean ($\hat{\varepsilon}_j^1$)		-0.2222	-0.2111	-0.2051	-0.1219
Variance ($\hat{\varepsilon}_j^1$)		0.3743	0.3229	0.3951	0.4307
Mean ($\hat{\varepsilon}_i^1$)		-0.0212	-0.0190	-0.0259	-0.0219
Variance ($\hat{\varepsilon}_i^1$)		1.0783	1.0592	1.1450	1.1925
State 2:					
Mean ($\hat{\varepsilon}_j^2$)		0.0218	0.0195	0.0268	0.0239
Variance ($\hat{\varepsilon}_j^2$)		0.7558	0.7738	0.7492	0.7629
Mean ($\hat{\varepsilon}_i^2$)		-0.4586	-0.5465	-0.4494	-0.3449
Variance ($\hat{\varepsilon}_i^2$)		0.6130	0.6244	0.6389	0.7244

Table 11: Estimation Results of the Burr Models for the other currency pairs, c_m is the constant, γ_{pl} corresponds to profits, γ_{vo} to volume, γ_{s1} to duration of previous roundtrip state, γ_{s2} to duration of previous inactivity state, γ_{dco} to complex trading strategies, γ_{do} to limit order in opening, γ_{dc} to limit order in closing, γ_{ds} to short in base currency, γ_{da} to account in EUR. α_m, σ^2 are parameters of the (baseline) hazard. Values in parenthesis () report the corresponding standard deviation. **Bold** numbers denote coefficients, which are not significant on the 5% level.

State	Parameter	Burr Model	State	Parameter	Burr Model	
State 1 (Round-trip)	c_1	-2.467 (.3123)		γ_{lodoc}	0.028 (.0168)	
	γ_{dpr}	0.898 (.1064)		γ_{lodsl}	-0.087 (.0240)	
	γ_{dprdsm}	0.296 (.1093)		γ_{pr^2}	0.017 (.0066)	
	γ_{dprdbi}	0.199 (.2843)		γ_{lo^2}	0.004 (.0070)	
	γ_{dprdoc}	0.027 (.0776)		γ_{vo}	0.434 (.0351)	
	γ_{dprdsl}	-0.039 (.0931)		γ_{s1}	-0.267 (.0091)	
	γ_{dlo}	1.484 (.1045)		γ_{s2}	-0.073 (.0053)	
	γ_{dlodsm}	0.210 (.1622)		γ_{dco}	-1.453 (.0436)	
	γ_{dlodbi}	-0.220 (.2263)		γ_{do}	-0.279 (.0445)	
	γ_{dlodoc}	-0.139 (.0556)		γ_{dc}	-0.330 (.0802)	
	γ_{dlodsl}	0.005 (.0604)		γ_{ds}	0.074 (.0191)	
	γ_{pr}	-0.798 (.0550)		γ_{da}	0.128 (.0610)	
	γ_{prdsm}	-0.909 (.0716)		α_1	0.942 (.0204)	
	γ_{prdbi}	0.066 (.0595)		σ^2	0.841 (.0412)	
	γ_{prdoc}	-0.004 (.0273)		State 2 (Inactivity)	c_2	-0.334 (.0630)
	γ_{prdsl}	0.006 (.0207)			α_2	0.484 (.0079)
	γ_{lo}	0.821 (.0519)		State 3	c_3	-6.325 (.0840)
γ_{lodsm}	0.852 (.0948)	State 4	c_4	-7.105 (.0253)		
γ_{lodbi}	-0.157 (.0487)					
Observations	122819					
Mean log-likelih.	-2.51013					
LR-Test	11689 (.0000)					
Residual Analysis						
Joint:			State 1:			
Mean ($\hat{\varepsilon}_j$)	0.0000		Mean ($\hat{\varepsilon}_i^1$)	-0.1483		
Variance ($\hat{\varepsilon}_j$)	0.9273		Variance ($\hat{\varepsilon}_i^1$)	0.3170		
Mean ($\hat{\varepsilon}_i$)	-0.2833		State 2:			
Variance ($\hat{\varepsilon}_i$)	0.2422		Mean ($\hat{\varepsilon}_j^2$)	0.0192		
State 1:			Variance ($\hat{\varepsilon}_j^2$)	0.7734		
Mean ($\hat{\varepsilon}_j^1$)	-0.0187		Mean ($\hat{\varepsilon}_i^2$)	-0.4704		
Variance ($\hat{\varepsilon}_j^1$)	1.0764		Variance ($\hat{\varepsilon}_i^2$)	0.6381		

Table 12: Estimation Results of the augmented Burr Model for the GBP/USD currency pair. Values in parenthesis () report the corresponding standard deviation. **Bold** numbers denote coefficients, which are not significant on the 5% level.

State	Parameter	Burr Model	State	Parameter	Burr Model	
State 1 (Round-trip)	c_1	-3.357 (.2719)	State 2 (Inactivity)	γ_{lodoc}	0.017 (.0166)	
	γ_{dpr}	1.109 (.1017)		γ_{lodsl}	-0.048 (.0241)	
	γ_{dprdsm}	0.129 (.1308)		γ_{pr^2}	0.021 (.0070)	
	γ_{dprdbi}	0.098 (.1722)		γ_{lo^2}	-0.003 (.0064)	
	γ_{dprdoc}	0.027 (.0368)		γ_{vo}	0.457 (.0293)	
	γ_{dprdsl}	-0.106 (.1691)		γ_{s1}	-0.249 (.0111)	
	γ_{dlo}	1.378 (.1151)		γ_{s2}	-0.078 (.0064)	
	γ_{dlodsm}	0.165 (.1312)		γ_{dco}	-1.336 (.0524)	
	γ_{dlodbi}	-0.498 (.2158)		γ_{do}	-0.120 (.0587)	
	γ_{dlodoc}	-0.184 (.0554)		γ_{dc}	-0.108 (.1476)	
	γ_{dlodsl}	0.031 (.1243)		γ_{ds}	0.128 (.0238)	
	γ_{pr}	-0.876 (.0503)		γ_{da}	0.255 (.1094)	
	γ_{prdsm}	-1.189 (.1175)		α_1	0.894 (.0228)	
	γ_{prdbi}	0.094 (.0449)		σ^2	0.773 (.0482)	
	γ_{prdoc}	-0.010 (.0137)		State 3	c_3	-6.279 (.0966)
	γ_{prdsl}	-0.003 (.0273)		State 4	c_4	-7.176 (.0269)
	γ_{lo}	0.774 (.0544)				
γ_{lodsm}	0.851 (.0883)					
γ_{lodbi}	-0.202 (.0480)					
Observations	90924					
Mean log-likelih.	-2.75459					
LR-Test	9627 (.0000)					
Residual Analysis						
Joint:			State 1:			
Mean ($\hat{\epsilon}_j$)	0.0000		Mean ($\hat{\epsilon}_i^1$)	-0.1178		
Variance ($\hat{\epsilon}_j$)	0.9316		Variance ($\hat{\epsilon}_i^1$)	0.2906		
Mean ($\hat{\epsilon}_i$)	-0.3049		State 2:			
Variance ($\hat{\epsilon}_i$)	0.2221		Mean ($\hat{\epsilon}_j^2$)	0.0175		
State 1:			Variance ($\hat{\epsilon}_j^2$)	0.7878		
Mean ($\hat{\epsilon}_j^1$)	-0.0170		Mean ($\hat{\epsilon}_i^2$)	-0.5563		
Variance ($\hat{\epsilon}_j^1$)	1.0708		Variance ($\hat{\epsilon}_i^2$)	0.6443		

Table 13: Estimation Results of the augmented Burr Model for the AUD/USD currency pair. Values in parenthesis () report the corresponding standard deviation. **Bold** numbers denote coefficients, which are not significant on the 5% level.

State	Parameter	Burr Model	State	Parameter	Burr Model	
State 1 (Round-trip)	c_1	-2.276 (.3107)		γ_{lodic}	-0.008 (.0187)	
	γ_{dpr}	0.916 (.1280)		γ_{lodsl}	-0.139 (.0340)	
	γ_{dprdsm}	0.115 (.1173)		γ_{pr^2}	0.012 (.0054)	
	γ_{dprdbi}	0.204 (.1545)		γ_{lo^2}	0.016 (.0080)	
	γ_{dprdoc}	0.037 (.0468)		γ_{vo}	0.323 (.0336)	
	γ_{dprdsl}	-0.031 (.1492)		γ_{s1}	-0.221 (.0090)	
	γ_{dlo}	1.725 (.1194)		γ_{s2}	-0.055 (.0053)	
	γ_{dlodsm}	-0.149 (.1918)		γ_{dco}	-1.288 (.0480)	
	γ_{dlodbi}	0.221 (.1994)		γ_{do}	-0.187 (.0442)	
	γ_{dlodoc}	-0.264 (.0648)		γ_{dc}	-0.205 (.1403)	
	γ_{dlodsl}	-0.086 (.1685)		γ_{ds}	-0.019 (.0211)	
	γ_{pr}	-0.652 (.0530)		γ_{da}	0.107 (.0673)	
	γ_{prdsm}	-0.828 (.0908)		α_1	0.837 (.0173)	
	γ_{prdbi}	0.079 (.0399)		σ^2	0.626 (.0336)	
	γ_{prdoc}	-0.033 (.0148)		State 2 (Inactivity)	c_2	-0.604 (.0544)
	γ_{prdsl}	0.016 (.0201)			α_2	0.443 (.0071)
	γ_{lo}	0.838 (.0549)		State 3	c_3	-6.693 (.0951)
γ_{lodsm}	0.705 (.1057)	State 4	c_4	-7.230 (.0256)		
γ_{lodbi}	-0.093 (.0507)					
Observations	85091					
mean log-likelih.	-2.93242					
LR-Test	7898 (.0000)					
Residual Analysis						
Joint:			State 1:			
Mean ($\hat{\epsilon}_j$)	0.0000		Mean ($\hat{\epsilon}_i^1$)	-0.1222		
Variance ($\hat{\epsilon}_j$)	0.9559		Variance ($\hat{\epsilon}_i^1$)	0.3068		
Mean ($\hat{\epsilon}_i$)	-0.2584		State 2:			
Variance ($\hat{\epsilon}_i$)	0.2206		Mean ($\hat{\epsilon}_j^2$)	0.0241		
State 1:			Variance ($\hat{\epsilon}_j^2$)	0.7649		
Mean ($\hat{\epsilon}_j^1$)	-0.0233		Mean ($\hat{\epsilon}_i^2$)	-0.4599		
Variance ($\hat{\epsilon}_j^1$)	1.1394		Variance ($\hat{\epsilon}_i^2$)	0.6625		

Table 14: Estimation Results of the augmented Burr Model for the USD/CHF currency pair. Values in parenthesis () report the corresponding standard deviation. **Bold** numbers denote coefficients, which are not significant on the 5% level.

State	Parameter	Burr Model	State	Parameter	Burr Model	
State 1 (Round-trip)	c_1	-3.522 (.4409)		γ_{lodoc}	-0.009 (.0280)	
	γ_{dpr}	1.843 (.3102)		γ_{lodsl}	-0.149 (.0453)	
	γ_{dprdsm}	-0.197 (.1332)		γ_{pr^2}	0.050 (.0110)	
	γ_{dprdbi}	0.773 (.7169)		γ_{lo^2}	0.026 (.0126)	
	γ_{dprdoc}	-0.078 (.0768)		γ_{vo}	0.325 (.0332)	
	γ_{dprdsl}	-0.975 (.1443)		γ_{s1}	-0.194 (.0157)	
	γ_{dlo}	2.163 (.3504)		γ_{s2}	-0.035 (.0100)	
	γ_{dlodsm}	-0.241 (.2220)		γ_{dco}	-1.217 (.0725)	
	γ_{dlodbi}	0.145 (.5717)		γ_{do}	-0.064 (.0739)	
	γ_{dlodoc}	-0.301 (.1149)		γ_{dc}	0.790 (.1253)	
	γ_{dlodsl}	-0.701 (.2008)		γ_{ds}	0.036 (.0464)	
	γ_{pr}	-0.865 (.0835)		γ_{da}	-0.110 (.1161)	
	γ_{prdsm}	-0.235 (.0949)		α_1	0.752 (.0232)	
	γ_{prdbi}	-0.076 (.1201)		σ^2	0.378 (.0367)	
	γ_{prdoc}	-0.008 (.0247)		State 2 (Inactivity)	c_2	-1.286 (.0814)
	γ_{prdsl}	0.094 (.0341)			α_2	0.431 (.0160)
	γ_{lo}	0.851 (.1119)		State 3	c_3	-6.490 (.1684)
γ_{lodsm}	0.134 (.1170)	State 4	c_4	-7.436 (.0384)		
γ_{lodbi}	-0.038 (.1028)					
Observations	10642					
Mean log-likelih.	-4.08997					
LR-Test	962.7 (.0000)					
Residual Analysis						
Joint:			State 1:			
Mean ($\hat{\varepsilon}_j$)	0.0000		Mean ($\hat{\varepsilon}_i^1$)	-0.0855		
Variance ($\hat{\varepsilon}_j$)	0.9937		Variance ($\hat{\varepsilon}_i^1$)	0.4288		
Mean ($\hat{\varepsilon}_i$)	-0.1830		State 2:			
Variance ($\hat{\varepsilon}_i$)	0.2824		Mean ($\hat{\varepsilon}_j^2$)	0.0243		
State 1:			Variance ($\hat{\varepsilon}_j^2$)	0.7609		
Mean ($\hat{\varepsilon}_j^1$)	-0.0222		Mean ($\hat{\varepsilon}_i^2$)	-0.3438		
Variance ($\hat{\varepsilon}_j^1$)	1.2057		Variance ($\hat{\varepsilon}_i^2$)	0.7216		

Table 15: Estimation Results of the augmented Burr Model for the GBP/CHF currency pair. Values in parenthesis () report the corresponding standard deviation. **Bold** numbers denote coefficients, which are not significant on the 5% level.