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Behavioral Finance Meets Experimental Macroeconomics: On the Determinants of Currency Trade Decisions

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A novel approach which conjoins elements of experimental macroeconomics and behavioral finance allows us to study the components of industrial firms' currency trade decisions in the controlled environment of a laboratory. We analyze how firms operate in the currency market in a deterministic two-country model with two currencies. Consistent with presumptions of real-world behavior, subjects in our experiment tend to base their trade decisions on definite rather than on uncertain key data: Interest rates have a high impact, while technical analysis plays a minor role. We finally demonstrate how a simple decision rule that incorporates our findings might outperform the actually observed trade decisions.

Keywords: Currency trade, Exchange rate uncertainty, Laboratory experiment

INTRODUCTION

Currency trade has always had a vast influence on systems of flexible exchange rates. A large variety of empirical, experimental, computational, and theoretical investigations deals with this topic. But what determines the currency trade decision of a firm? Why do nonfinancial firms speculate? How do they deal with exchange rate uncertainty? In this paper, we describe evidence from a computerized laboratory experiment in which industrial firms have the opportunity to produce a consumption good as well as trade with currency. This is a unique approach since it lies in the intersection between behavioral finance and experimental macroeconomics, and it is to the best of our knowledge the first study to cover this topic.

In traditional economics, currency trade behavior is usually explored by evaluating empirical field data. As a complement, the controlled environment of a laboratory experiment allows us to abstract from problems that are prevalent when using field data. In the lab, every trader has identical sources and channels of information, the prevailing circumstances are the same, the endowments of the traders can be kept at equal level, and external shocks can be controlled for. Yet it is important to utilize an appropriate experimental model which describes an exchange rate mechanism. There exist some experimental designs of international economies in literature which describe the mechanism of exchange rate determination. For example, Noussair et al. [2006] derive the exchange rate from the flow of funds theory of exchange rates and use the import and the price of goods as components of the exchange rate in a complex three-country model. An earlier article by Noussair et al. [1997] features the same model of exchange rate determination in a two-country model but with fewer agents and fewer markets. The model described by Arifovic [1996] utilizes a purchasing power parity model for the calculation of the exchange rate. In contrast to exchange rate determination based on international trade of goods or purchasing power parity, Fisher and Kelly [2000] let traders buy or sell two foreign currencies and one home currency in a double auction. Thus, the exchange rates are the average relative prices paid by currency traders. Note that all models take into account either international trade, purchasing power parity, or currency amounts offered. Contrarily, Pope et al.

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[2003] create a synthesis of external key features in which currency trade, international trade of goods and materials, and central bank interventions determine the exchange rate. Using this model allows us to focus on the influence of different economic figures on the currency trade decision of firms.

We show that in our experiment the influence of technical analysis on the currency trade decision is rather weak compared to other determinants. In accordance to this, Cheung and Chinn [2001] show in a market survey study that only 30% of U.S. foreign exchange traders (at most) use technical analysis of exchange rates as a means of determination of currency trade decisions. In the same publication, the authors show that the importance of individual macroeconomic variables shifts over time, although the influence of interest rates is of constant importance. Cheung et al. [2004] describe a survey of U.K.-based traders in 1998 regarding their beliefs on the importance of macroeconomic factors on exchange rates. They conclude that the traders think exchange rates are determined in the long run by economic fundamental values and in the short run by overreaction, speculation, and bandwagon effects. Our data suggest that a large proportion of subjects indeed adapt their trade behavior to economic figures besides interest and exchange rates. Moreover, subjects who neglect the variation of previous consecutive exchange rates and instead base their decision solely on the difference of the interest rates in the countries scoop in the highest currency trade profits in our experiment.

The remainder of this paper is organized as follows. First, we give a brief introduction on the experimental design. Subsequently, the results are presented, starting by identifying possible determinants of the firms' currency trade behavior in our experiment. Afterward, we compare the profitability of different trade strategies and propose a simple decision rule that outperforms the actually observed trade decisions. Finally, we discuss our findings and conclude.

EXPERIMENTAL DESIGN

We use a symmetric and deterministic two-country model as described by Pope, Selten, and von Hagen [2003]. The model has a game-theoretical equilibrium solution that unfortunately cannot be discussed here in detail due to space constraints. For the same reason, we will limit its description to the mechanisms that are directly related to currency trade and exchange rate determination. The interested reader can find all details of the model and the game-theoretical solution in Pope et al. [2003].

The game features two countries A and B. In each country, nine players act as economic entities in a round-based experiment: one government, one central bank, one labor union, one employers' association, and five firms. Since the model is symmetric, let us fix a home country and view everything from its perspective, denoting the parameters of the foreign country by an asterisk. Two types of goods exist in each country: a consumption good Q that is produced by the firms in the country and a material M. While the consumption good is a domestic good, material is traded internationally: firms need materials from *both* countries, M and M^*, for production.

The model spans over multiple periods. Each period consists of a number of successive steps. In each step, the respective players choose their decision variable(s) simultaneously. After each step, the decisions are made public.

First, the government chooses the total nominal expenditures D of the economy by means of fiscal policy. Expenditures are spent exclusively on the domestic consumption good Q. Second, the central banks have to decide on three variables: They set the interest factor r (defined as the percentage interest rate plus one) for their country, fix an exchange rate aim f, and choose next period's target price p_+ for the domestic consumption good.[1] Subsequently, the union representative and the employers' association of each country bargain on the nominal wage rate w, that is, the price for one unit of local labor. If the union and the employers' association do not agree on a common wage, the wage is set to a statutory minimum wage $w_0 = \eta p$ and there will be a strike in the corresponding country. A strike reduces firms' maximum production capacity Q_c to $Q_0 < Q_c$, and also decreases the demand D for the produced consumption good to σD.

Finally, firms know the amount of total nominal expenditures to be spent on the consumption good and also how much they have to pay for interest and labor. Firm i decides on its production quantity Q_i, which has to be above a minimum production quantity Q_m and below the capacity constraint Q_c. Firms within a country interact in a Cournot market for consumption goods, so the price q for one unit of the consumption good is defined as $q = D/Q (q = \sigma D/\mathrm{Q}$ in case of strike), with $Q = \sum_i Q_i$. Contrarily, the market for materials is modeled to be competitive. For producing one unit of material, one unit of local labor is needed at cost w. Wage payments are paid before interest, so the marginal costs of one unit of material, that is, the price for the material, are m=wr, resp. $m^* = w^* r^*$. To produce the good, a firm needs labor, home material (M), and foreign material (M^*). The labor L_i consists of fixed labor F, which is needed to run the company, and variable labor, which is equal to Q_i.

Besides the production task, firms may engage in currency transactions which will be in the focus of our interest in the remainder of this article. A firm can borrow money for one period either from its home or foreign central bank at the interest factor r resp. r^* and offers it on the currency market, whereupon X_i (X_i^*) is the amount of home (foreign[2]) currency offered. Money borrowed is paid back in the next period including interest, so a first potential trade gain/loss stems from the difference in interest rates of the two countries.

At the end of each round, a firm's home (S_i) and foreign (S_i^*) account totals to[3]:

$$S_i = Q_i q + r(X_i^* e - L_i w - X_i) - M_i m \tag{1}$$

$$S_i^* = r^*(X_i e^* - X_i^*) - M_i^* m \tag{2}$$

The last steps of a round do not require player interaction. First, the actual exchange rate is determined (see below). Then, all costs and revenues incurred by production and currency trade of a firm i get deducted from, and transferred to, respectively, the corresponding home or foreign account. The final account balances (positive as well as negative) are taken over by the firm's owner, clearing the account for the next period.

Notice that at the time a firm offers currency, the actual exchange rate e is not yet determined. Furthermore, notice that the firm owners consume their profits in the next period in their home country; thus, they have to trade the money from the foreign account back into their home currency at next period's exchange rate e_+, so that the second potential currency trade gain/loss stems from the difference between the two consecutive exchange rates e and e_+. Summarizing, the payoff function of firm i is defined as expenditure deflated profit[4]:

$$v_i = \frac{S_i + e_+ S_i^*}{D} \tag{3}$$

which can be decomposed into production profits and currency trade profits; the latter being given by:

$$v_{\text{trade}} = \frac{\left(\frac{e_+ r^*}{e} - r\right)(X_i - X_i^* e)}{D} \tag{4}$$

Due to the richness of factors for a firm's profit, each firm has the possibility to utilize a profit calculator (see Figure 4). The players can enter their own estimates for this period's ($\hat{e}$) and next period's exchange rate ($\hat{e}_+$), as well as for the total production quantity of the other firms in their country. A firm then selects a grid constant $\hat{s}$ for the profit table, which displays its own production quantity $\hat{Q}_i$ on the ordinate, the total production of the other firms on the abscissa, and the corresponding expected profits in the fields. Furthermore, the profit calculator suggests which currency offer would be the most remunerative if the exchange rate estimates entered were correct. The currency trade suggestion takes the differences of the interest factors of both countries into account. Let $h := (r^* \hat{e}_+ / \hat{e}) – r$. The trade advice will then be i) 'offer home currency' if $h > 0$, ii) 'offer foreign currency' if $h < 0$, or iii) 'don't offer currency' if $h = 0$.

The actual exchange rate is determined in a deterministic way by a mechanism which takes the central bank's exchange rate aims f and f^* into account. If both exchange rate aims are the same ($f = 1/f^*$), the exchange rate e will be set to f. Otherwise, the central banks will automatically intervene on the currency market. The size of the central banks offer of home currency I depends on the previous period's raw materials price m_- and a positive constant ζ_j ($j \in 1,2$):

$$I = \begin{cases} \zeta_1 m_- & \text{if } f > \frac{1}{f^*} \quad \text{(low aim conflict)} \\ \zeta_2 m_- & \text{if } f < \frac{1}{f^*} \quad \text{(high aim conflict)} \end{cases} \tag{5}$$

Analogously, the central banks' foreign currency offer:

$$I^* = \begin{cases} \zeta_1 m_-^* & \text{if } f > \frac{1}{f^*} \quad \text{(low aim conflict)} \\ \zeta_2 m_-^* & \text{if } f < \frac{1}{f^*} \quad \text{(high aim conflict)} \end{cases} \tag{6}$$

with $\zeta_1 \geq \zeta_2$. The tentative exchange rate $\bar{e}$ is defined as the ratio of the total currency offers:

$$\bar{e} = \frac{X + K_- + I}{X^* + K_-^* + I^*} \tag{7}$$

Based on this measure, the actual exchange rate e is determined as:

$$e = \begin{cases} \min\left(f, \frac{1}{f^*}\right) & \text{for } \bar{e} \leq \min\left(f, \frac{1}{f^*}\right) \\ \bar{e} & \text{for } \min\left(f, \frac{1}{f^*}\right) < \bar{e} < \max\left(f, \frac{1}{f^*}\right) \\ \max\left(f, \frac{1}{f^*}\right) & \text{for } \bar{e} \geq \max\left(f, \frac{1}{f^*}\right) \end{cases} \tag{8}$$

Using the notion of an incomplete equilibrium[5] as developed in Pope et al. [2003], one can show that the equilibrium decision of each firm is to offer the Cournot quantity of $Q_i^C = 40$. Concerning a firm's currency trade decision, it should always equal zero, since in equilibrium exchange rates should be stable and interest factors should be equal across countries[6]. However, off-equilibrium a rational firm player should decide according to above currency trade suggestion, that is, offer home currency if $\frac{e_+}{e} r^* > r$ or offer foreign currency if $\frac{e_+}{e} r^* < r$.

The experiments were conducted as computer-based experiments in the Laboratory for Experimental Economics of the University of Bonn between January 2002 and June 2005. All participants have been students of economics for at least two years and were only allowed to participate once. Before the game started, written instructions were handed out to the participants. Thereafter, an introduction of about one hour was given to them including example calculations of various figures. Some control questions were posed, and after subjects gave the right answers, the roles were assigned by chance, and the experiment started. One session lasted approximately eight hours, including a lunch break of one hour. After a debriefing, participants were given their converted cumulative round payoffs in Euros (at a rate of €250 per point), including a show-up fee of €5. The average hourly payoff was €10.23. Altogether, 9 sessions with 18 subjects each were conducted. Hence, a total of 90 subjects have taken part in the experiments as firm players.

RESULTS

The rich and controlled environment of our experiment allows us to study possible determinants of firms' currency

TABLE 1
2 × 2 Table for the Computation of Yule Coefficients.

	Offer Foreign Currency	Offer Home Currency
$\Delta r_t > 0$	y_f^+	y_h^-
$\Delta r_t < 0$	y_f^-	y_h^+

trade decisions. Our database consists of 1,800 trade decisions in 9 sessions with 20 periods by 10 subjects each. In 1,327 of those, a positive offer of either home (549) or foreign (778) currency was placed. In the following subsections, we focus on the determinants that are frequently suggested to impact trade decisions in the field (see Keloharju and Niskanen [2001] and Cheung and Chinn [2001]): interest rate differences and technical analysis. As will be shown, subjects' behavior is heterogeneous and a number of motives are prominent in the data; yet there is evidence that the success (in terms of monetary profit) differs significantly between the trade strategies.

Interest Rate Differences

Firms that base their currency trade decision solely on the interest difference should offer home currency if $\Delta r_t < 0$, foreign currency if $\Delta r_t > 0$, and no currency if $\Delta r_t > 0$ (cf. equation 4); where $\Delta r_t = r_t – r_t^*$ is the difference between the domestic and the foreign interest rate in period t. To check if some subjects base their trade decision on the interest rate difference, we examine all periods in which a difference in interest factors arose and a firm traded currency. We then count how often home or foreign currency was offered. This provides us with a 2×2 table for each firm player as shown in Table 1.

For each firm, such a 2×2 table has been determined. If a table displays high scores for y_f^+ and y_h^+ and low scores for y_f^- and y_h^-, it hints at a strong influence of the interest rate difference on the corresponding subjects' trade decisions; he offers foreign currency when the home interest rate exceeds the foreign interest rate y_f^+, and offers home currency when the foreign interest rate is greater than the home interest rate y_h^+—but not vice versa. To have an exact measure for this coherence, we calculate a Yule coefficient for each subject:

$$Y = \frac{y_f^+ \cdot y_h^+ - y_f^- \cdot y_h^-}{y_f^+ \cdot y_h^+ + y_f^- \cdot y_h^-} \tag{9}$$

The Yule coefficient ranges from $-1 \leq Y \leq 1$; and Y equals 1 for subjects placing their currency trades always in line with the interest rate difference.[7] As can be seen in Figure 1, the majority (47) of the subjects in our experiment have $Y = 1$. Moreover, if we classify firms with $Y \geq 0.5$ as interest factor difference oriented subjects, 84% of the firms belong to this group. The median (average) of the Yule coefficients' distribution is 1 (.72). Only eight subjects have $Y < 0$, four of them at the extreme $Y = -1$. All session averages of Y are positive (signed-rank test, $p < 0.01$). Overall, we observe a clear tendency that subjects use currency trade strategies which are based on interest rate differences.

Note that the trade advice given by the profit calculator, besides using the subject's exchange rate change belief, also takes the actual interest rates into account—so subjects might be following the advice rather than be consciously reacting to the interest rates. As a matter of fact, the profit calculator is used quite frequently, and if it is used, firms' trade decisions usually follow the advice (in 81% of all cases).[8] However, if we examine the 218 decisions where no advice is requested and interest rates differ across countries, we again find strong

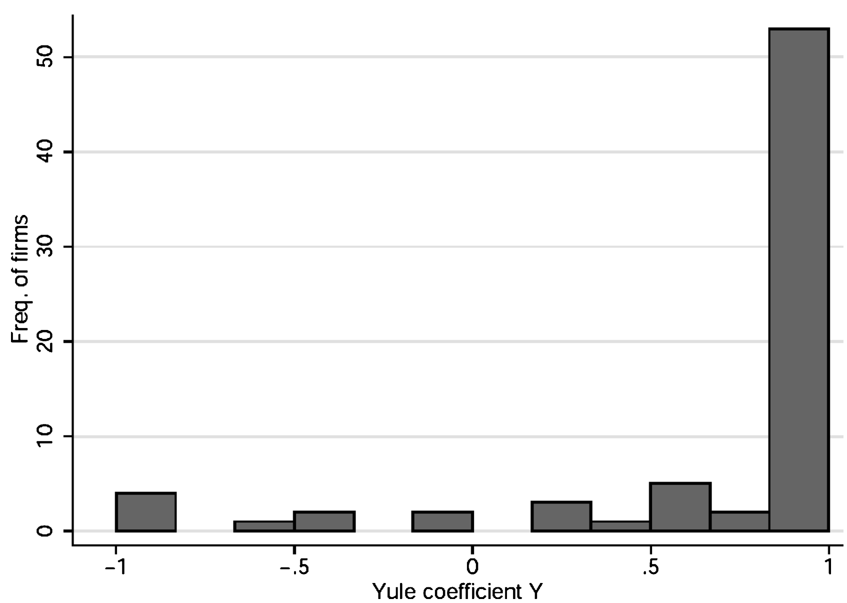

FIGURE 1 Distribution of the Yule coefficient.

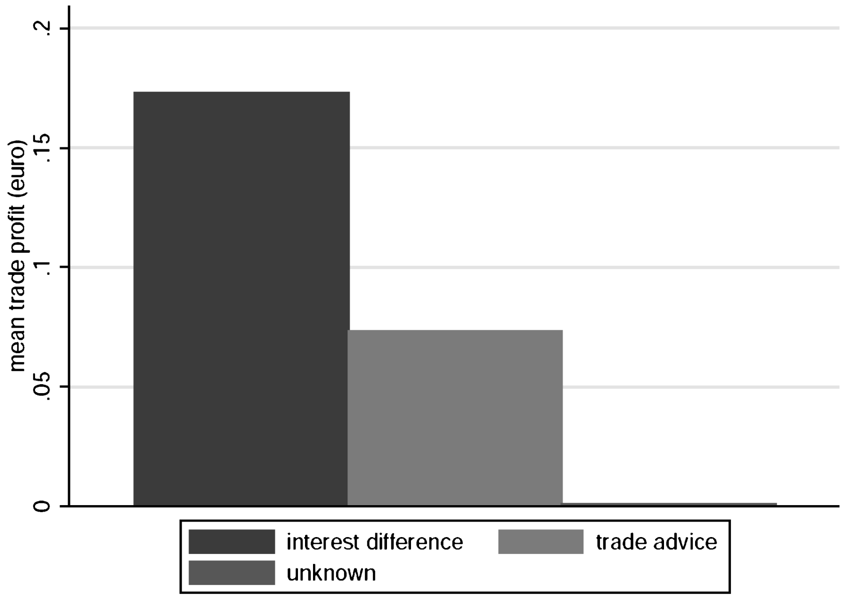

FIGURE 2 Mean period profit for different classes of trade decisions.

evidence for the importance of the interest rate difference; most of these decisions (approximately 61%) are in line with the interest rate. In addition, in the 740 cases where an advice is requested and interest rates differ, only few decisions (approximately 30%) are not in line with the interest rate. Taken together, our findings concerning the importance of the interest rate difference for subjects' currency trade decisions can be summarized as follows.

> **Result 1**: The interest difference across countries plays a crucial role for firms' currency trade decisions. Subjects' decisions are not only consciously linked to the interest rates, but also indirectly when following the trade advice given by the profit calculator.

Profitability of Trade Decisions

As we already demonstrated in the previous section, some trade decisions rigorously follow the currency trade advice, some of them go in the opposite direction because the difference in interest factors is in favor of the other currency, and the rest base their trade decision on some other, unidentifiable strategies. In this section, we will now compare the profitability of the different trading strategies, resp. classes, which we denote by h (trade advice), Δr_t(interest difference), and u (other strategies).

The average values of the currency trade profit v_{trade} for each class of trade decisions are shown in Figure 2. The average period profit for h, Δr_t and u are 7.3, 18, and 0 Eurocents. As can be seen, the average profit per period for trades that are based solely on the interest rate change is significantly higher than the profit of trades that rely on the trade advice (signed-rank test, $p < 0.05$). Both are significantly higher than the profits from u (signed-rank tests, $p < 0.001$). The session means of h and Δr_t are always positive, whereas for u they are only positive in seven sessions.

Instead of treating each trade decision separately, one could also take a different approach and classify each subject according to his conformance to the three possible trading motives. However, doing so does not alter above results qualitatively.[9] Again, Δr_t-subjects earn higher currency-trade profits than h-subjects, and both earn significantly more than u-subjects (Fisher-Pitman test, $p = 0.016$ and $p = 0.031$).

The fact that the highest trade profits are based on interest rate change rather than on trade advice seems to be surprising. Since the trade advice takes additionally the expected exchange rate change into account, that is, it incorporates more information, one should naively expect that trade profits are highest for this class of decisions. If not, this might either be caused by a smaller variance in exchange rate changes than in interest rate differences—or because subjects frequently misjudge future exchange rate developments.

As can be read from Table 2, the former point cannot account for the observed differences in trade profits. The average exchange rate change is almost five times larger than the interest difference, and the maximum change is even eight

TABLE 2
Summary Statistics on Absolute Interest Factor Differences and Absolute Exchange Rate Changes.

Variable	n	Average	Std. Dev.	Max.
$\|\Delta r_t\|$	175[a]	.0106883	.0146039	.096
$\|e/e_+ - 1\|$	180	.0531488	.1190195	.7682168

[a] Five observations have been excluded due to obvious typing errors.

times higher. This means that the most profitable decision class would be h, but only if the exchange rate variation was guessed correctly. If the variation estimate was wrong, the other two classes could scoop in higher profits. The comparison of the exchange rate estimates that subjects enter into the profit calculator with the actual exchange rates shows that subjects frequently guessed incorrectly. Recall that the trade advice h takes into account only the relation of $\hat{e}$ to $\hat{e}_+$, so subjects do not even need to guess the absolute values correctly. Nevertheless the estimated percentage change of the exchange rate has been correct in only 12% of all profit calculator utilizations. Moreover, 155 of the 158 correct estimates have been true predictions of no exchange rate change at all. The observed Spearman rank correlation between estimated and actual change equals only $\rho = 0.0017$. Taken together, great circumstantial evidence exists for the incapability of subjects to estimate changes in the exchange rate correctly, and due to this, trade profits are highest if based solely on interest rate difference.

Result 2: Large exchange rate changes call for supremacy of strategies that incorporate them into the trade decision. Although the trade advice given by the profit calculator does so, currency trade profits are actually higher if they are based exclusively on interest rate differences. The reason for this is the uncertainty of future exchange rate developments, and subjects' incapability of predicting the developments correctly.

Technical Analysis

Up to now, our findings suggest that most subjects ignore the exchange rate development at all. Those subjects who incorporate the exchange rate changes in their decision are outperformed by those who don't, since subjects are incapable of predicting the uncertain future exchange rate development correctly. However, several (professional) trade strategies outside the lab seem to be based on technical analysis, for example, chartist methods and mechanical rules (see Neely [1997] for a brief overview). Although one can already expect from our previous results that technical analysis plays only a minor role for subjects' trade decisions in our experiment, we examine in this section whether technical analysis can account for at least some parts of the observed behavior.

Note that decisions based on interest and exchange rate differences are not mutually exclusive—both determinants can point in the same direction, or there might be a trade-off going on between the two, which is unobservable from the data.[10] Consequently, it is difficult to separate between these two motives, resp. to classify decisions as we did in the previous analysis. Furthermore, almost all forms of technical trade would require large computational capacities, but subjects in our experiment are only equipped with an electronic calculator. So in order for technical analysis to stand a chance, we restrict our analysis to a simple strategy for estimating upcoming exchange rates: inferring the development from the difference between the previous period's exchange rate and the exchange rate in the period there before.[11]

For each player, we calculate the correlation between latest exchange rate changes and individual currency trade volumes; that is, we calculate Spearman's rho between $e_{t-1} - e_{t-2}$ and $X_i/\bar{X}_i + X_i^*/\bar{X}_i^*$ in period t.[12] The average absolute session values of this coefficient are quite similar across sessions. The overall mean (median) of the absolute coefficients equals .263 (.235), so we do find evidence for technical analysis in the observed behavior. Yet the influence of technical analysis is rather weak, especially if we compare it to the influence of interest rate differences: A similar measure between Δr_t and $X_i/\bar{X}_i + X_i^*/\bar{X}_i^*$ is in all but two sessions greater. The overall mean (median) of the absolute coefficients of this measure equals .316 (.311). The simple trend extrapolation thus has a significantly weaker influence on the trade decisions than interest differences (signed rank-test $p = 0.066$).

Result 3: Although subjects' capability of predicting future exchange rate development is rather poor, the observed currency trade behavior exhibits a degree of simple technical analysis; but still the influence of interest rate differences predominates.

A Simple Yet Smart Decision Rule

In this section, a very simple yet smart decision rule is developed, which is based on the previously reported results. So far, we saw that the difference in interest factors seems to be a profitable decision rule for trade decisions on average. In addition, subjects are incapable to accurately predict future exchange rates, and consequently make only minor use of technical analysis. To account for this, our postulated decision rule neglects uncertain estimates about future developments and incorporates only the presently available key data. Moreover, it does so in a very simple way to keep *cognitive* costs low:[13]

$$X = \begin{cases} \dot{X} & \text{if } \Delta r_t < 0 \\ 0 & \text{else} \end{cases} \tag{10}$$

$$X^* = \begin{cases} \frac{\dot{X}}{e_-} & \text{if } \Delta r_t > 0 \\ 0 & \text{else} \end{cases} \tag{11}$$

As can be seen, the decision rule postulates to always offer the currency that is profitable in view of the difference in present interest factors $r_t - r_t^*$. Also, it requires offering a constant amount of *value* $\dot{X}$ in each period; where $\dot{X}$ is a constant absolute amount in case of home currency being offered, and $\frac{\dot{X}}{e}$ is the corresponding amount in case of foreign currency being offered. Since the current exchange rate e is uncertain at the time of decision making, it is replaced by the previous period's exchange rate e_-.

To simplify the following computation, let us assume without loss of generality that $\dot{X} = 1$. We then calculate the

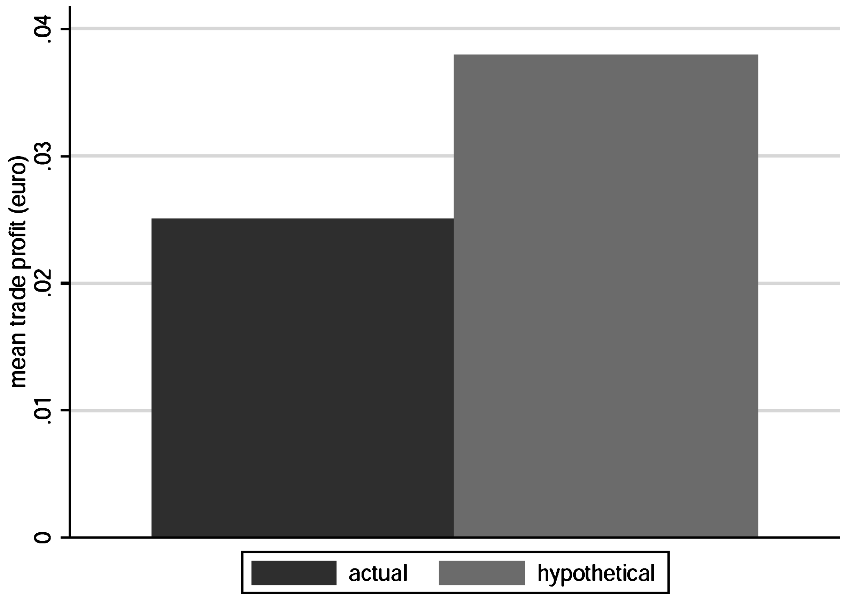

FIGURE 3 Comparison of mean actual and hypothetical normalized currency trade profits.

cumulative currency trade profits $\sum_t v_{\text{trade}}$ for a hypothetical firm which would have used our simple decision rule.[14] Computing $\sum_t v_{\text{trade}}$ for one firm in each country in all sessions, we only find one instance (out of 18) in which a firm would have made losses by applying this decision rule. In every other case, our decision rule performs quite successful. The average currency trade profit would have been .038 € per traded unit.

The right bar in Figure 3 depicts the average overall $\sum_t v_{\text{trade}}$ of the decision rule. In addition, it displays a comparable measure for the actually observed currency trade profits in our experiment. This measure is calculated by normalizing the currency trade profits of each subject in each period, that is, by dividing the currency trade profit by the amount of home currency offered, resp. by the amount of foreign currency offered times $1/e_{-}$. The average overall $\sum_t v_{\text{trade}}$ of actual trade decisions is .024 € per traded unit. Thus, the actually observed currency trade decisions are significantly outperformed by our simple decision rule (Fisher-Pitman test, $p = 0.0605$)—although this rule completely neglects possible trade profits which stem from exchange rate fluctuations. Even though it seems premature to conclude from this analysis that our simple decision rule is ultimately the best rule, in the light of almost zero cognitive costs it is surely a rule with an outstanding cost-benefit ratio.

Result 4: When future exchange rate development is uncertain, a simple rule which relies only on definite key data performs amazingly well. Not only does this simple decision rule outperform the actually observed trading behavior of the subjects, it does so at almost no cognitive costs: just offer a constant amount of home or foreign currency depending on the interest difference.

CONCLUDING REMARKS

We took a novel approach for analyzing currency trade decisions, by conjoining elements of behavioral finance and experimental macroeconomics. This unique realm was characterized by a rich experimental design (as introduced in Pope et al. [2003]), which tried to capture coherences from the real world as closely as was reasonable for a laboratory experiment.

In our experiment, subjects play the role of numerous institutions in a deterministic two-country model, which leaves wide scope for endogenous shocks and variations in key data like exchange rates and interest rates. Individual patterns of (not only) currency trade behavior emerged. We find that subjects tend to base their trade decisions on safe facts rather than on their beliefs about uncertain future developments. Present interest rates have the highest impact on individual trade decisions, yet we also observe forms of behavior that suggests that some subjects make use of simple forms of technical analysis (incorporating past exchange rate shifts). Although the variation of the exchange rate had the larger impact on the resulting payoff, we demonstrate that a simple yet smart decision rule, which incorporates our main findings and keeps cognitive costs to a minimum, on average would have outperformed the actually observed trade decisions of our subjects.

Up to now, almost all work done in the relevant research areas in macroeconomics and finance is either on empirical field-studies or solely based on theoretical frameworks: be it the analysis of currency trade and speculation behavior, or the influence of all kinds of shocks on economic performance, or the comparison of different exchange rate regimes or market forms, and so on. Our results and our approach inform many strands of this literature. We show which behavioral patterns persist in the controlled environment of a laboratory experiment and call attention to new questions that might be interesting to analyze in the future. Furthermore, we demonstrate how elements from experimental and behavioral economics can be applied to study traditional macroeconomic and financial topics in the controlled environment of a laboratory experiment.

Our findings are of importance for the advancement of (behavioral) theories of decision making under risk and uncertainty. We show that simple decision rules with low cognitive costs emerge also in more complex decision tasks than the ones that are usually studied and that they again perform quite successful. Our results also shed light on the relevance of the idea of ambiguity, resp. uncertainty aversion, and might help to develop new concepts which adequately mimic how people act in uncertain environments.

Our setup is highly stylized and thus cannot cover all features which might be desirable. Yet it might successively be enriched to study related topics. But there is also large room left for other future topics. One could think of a currency market in which both industrial firms and professional traders are involved and see if they behave differently. Also experiments that allow for currency crises or other financial phenomena such as bubbles, crashes, or fat tails might lead to new insights on how economic systems work. Furthermore, a model with three countries could give deeper insights on the strength of the determinants of the trade behavior. It would also be interesting to adjust the developed decision rule and to apply it to real-world data to check if or under which circumstances it still is a profitable decision rule. Our work and the work of Pope, Selten, and von Hagen should be seen as a starting point for future research. In general, this line of research is promising.

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NOTES

1. The exchange rate is defined as the price of one unit of foreign currency in home currency. The actual target price p equals p_+ in the last period, and is exogenously given in the first period. Note that in six sessions the exchange rate aims are not revealed to the firm players.
2. Note that here the asterisk denotes the currency rather than the country.
3. Consider that two credit constraints limit the firm accounts: The sum of labor costs and the amount of home currency offered must not exceed $C_1 = \gamma_1 w$, furthermore the maximum amount of foreign currency offered is $C_2 = \gamma_2 w*$. This limits the currency offers to: $\bar{X}_i = \gamma_1 w - L_i w$ and $\bar{X}_i^* = \gamma_2 w^*$. Parameter values are given in table 3 in the appendix.
4. The other players in the game are also paid contingent on their individual performance. For more details, confer Pope et al. [2003].
5. Note that we cannot solve this game using subgame perfection, because we do not have subgames after the first period due to incomplete information (e.g., firms do not know others production quantity and profits).
6. For a brief intuition about why this must hold, confer the central banks' objectives in Pope et al. [2003] and consider that the model is deterministic.
7. Note that this does not necessarily imply that subjects with a coefficient smaller than one do not take the interest rate difference into account. Such subjects might still follow a strategy that is based on the interest rates but in a more sophisticated way (or in a way which is based only partly on interest difference, but also on additional determinants). However, it seems natural (especially in view of the components r and $r*$ in the payoff formula) to assume that, if subjects focus on the interest rates, they should tend to offer the currency with the lower interest rate. Note that a Yule coefficient can only be determined if the denominator is not 0, which eliminates 28 subjects from our analysis.
8. Notice that the profit calculator could be used arbitrarily often per period, so the possibility of entering more than one guess for actual and upcoming exchange rates exists. Consequently, also different trade advices can occur within a period. However, 75.67% of the profit calculator utilizations were done with only one estimate for the exchange rates, and 94.45% were done with three estimates at most. For all cases where the profit calculator was used more than once per period, we only include the most recent estimates and advice in our analysis.
9. Yet interestingly, although the trade advice and the interest rate difference have such a strong influence on the trade decisions, the consistence of trade decisions *within subjects* is rather low. We find 18

subjects who mostly traded conforming to Δr_t , 26 to h, and 41 subjects who used different strategies. 5 subjects could not be uniquely classified and were excluded from this analysis.

10. With respect to this, also the trade advice in some sense might be interpreted as a mean for technical analysis.
11. We are aware that professional currency trading strategies based on technical analysis do not only take the exchange rate into account, but also incorporate further key data like central bank interventions or past trading volumes. Yet, consider that firms in our experiment lack knowledge about these data, since by design they don't know the size of central bank interventions, total firm currency offers, and foreign firm accounts. Hence in our design, the technical analysis of previous exchange rates is the only reasonable instrument for estimating future exchange rate development.
12. The latter is a standardized measure ranging between 0 and 1, which is calculated by dividing the actual currency offers by the maximum currency offers (cf. footnote 3). This is needed since the Spearman rho of the *absolute* trades would be confounded by the trade volume restrictions. Furthermore note that we use only the absolute value of the correlation coefficient, since we are interested in the strength of the correlation and not in its direction; different subjects might draw different conclusions from previous exchange rate changes.
13. Parts of the psychological literature suggest that cognitive costs play a crucial role in the process of decision making; for example, when faced with probabilistic decision problems, simple decision rules seems to be frequently (and successfully) used (Gigerenzer and Todd [1999]).
14. By fixing $\dot{X}$ to 1, we avoid exceeding the credit constraints for both accounts; otherwise, one would have additionally needed to control for the constraints. Furthermore, notice that throughout the computations, a possible influence of the currency offer on the exchange rate is neglected. This is justifiable since the influence of a single firm's currency offer (especially of only one unit) is only marginal at best.

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APPENDIX A: CALIBRATION

The design used for the experiment is a model invented by Pope, Selten and von Hagen for the purpose of exploring the effects of a currency union. It can be found in Pope et al. [2003]. The parameter specifications in Table 3 were used for the actual experiments.

TABLE 3
Parameter Values.

$Q_m = 20$	$\eta = 0.14$
$Q_c = 60$	$\zeta_1 = 600$
$Q_0 = 45$	$\zeta_2 = 500$
$\gamma_1 = 80$	$L_a = 600$
$\gamma_2 = 80$	$L_b = 720$
$\sigma = 0.6$	$r_0 = 1.05$
$F = 15$	

APPENDIX B: SCREENSHOTS

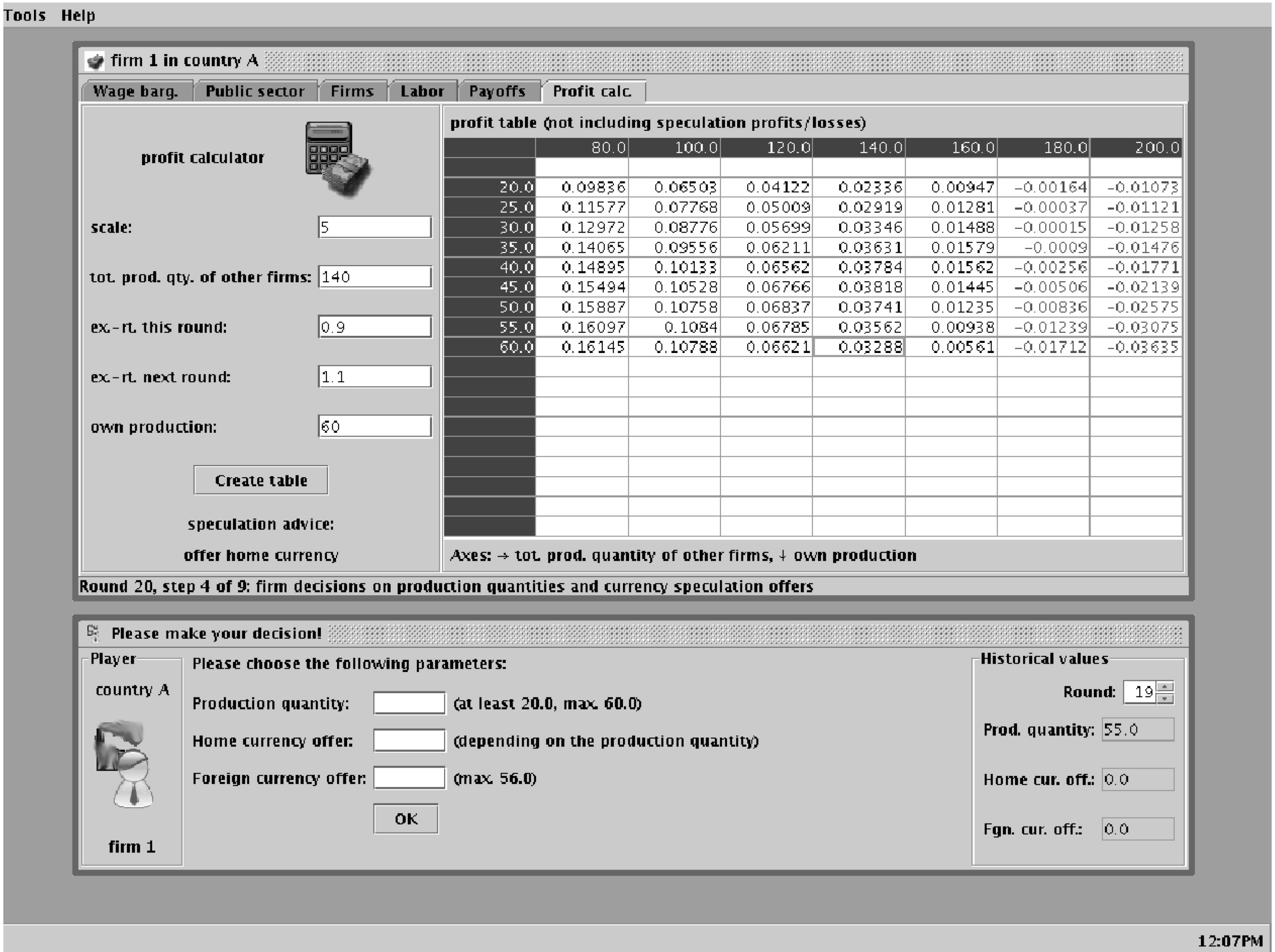

FIGURE 4 Screenshot of the firm's input frame.

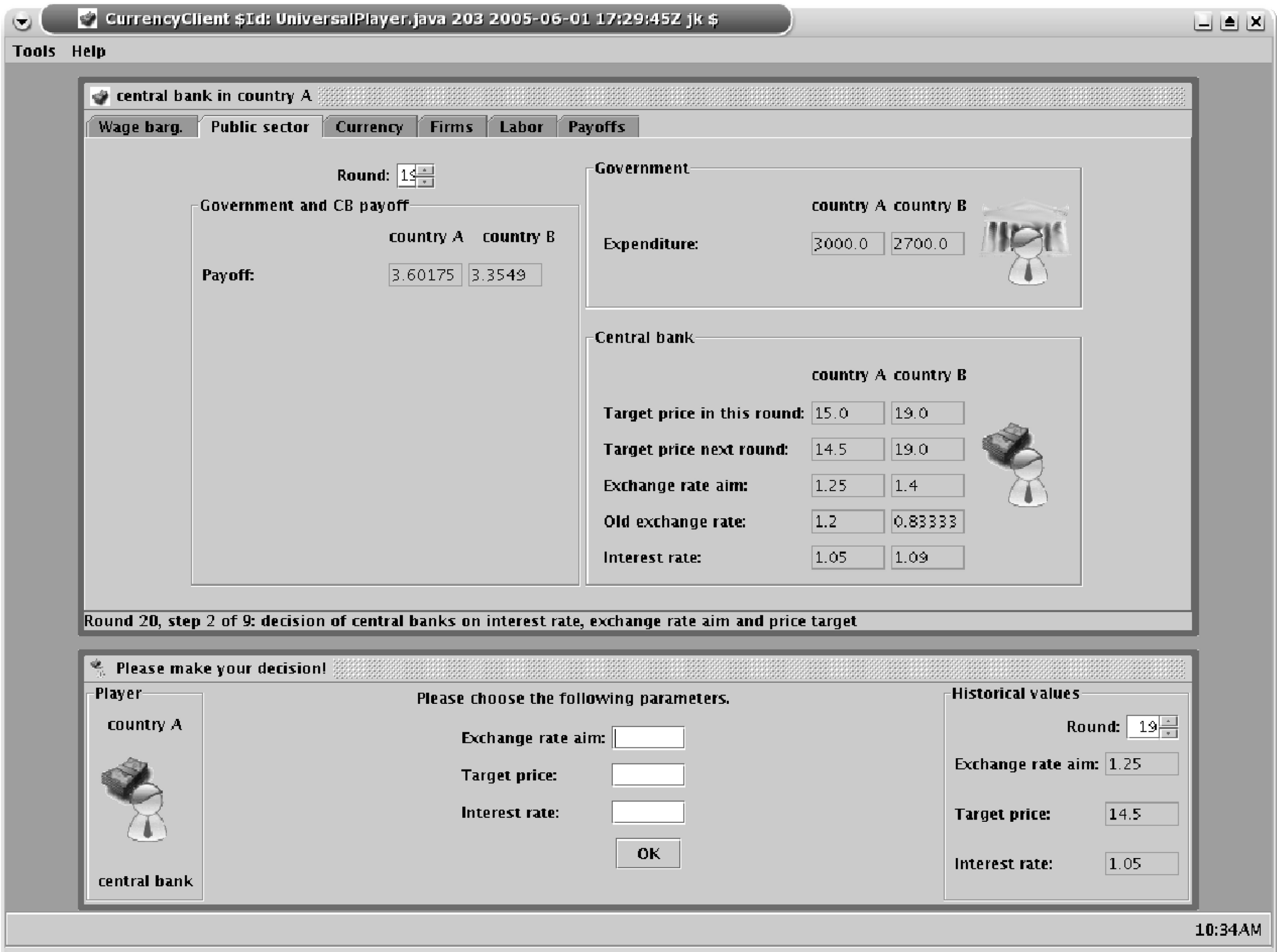

FIGURE 5 Screenshot of the central bank's input frame.