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Random risk aversion and the cost of eliminating the foreign exchange risk of the Euro

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Abstract

This paper answers the following questions. If the Euro foreign exchange risk is given, what is the cost of eliminating such a risk? How does risk aversion affect this cost? What is the relation between the insurance premium on the Euro and this cost? Is it possible to find out the level of risk aversion by looking upon actual risk-free yields? If risk aversion is random, how do risk-free yields move with the return on the Euro currency? Economists usually take for granted that preferences are stable. By contrast, business news networks mention frequently changing risk appetite, or changing investor sentiment, in order to explain market behavior. This paper shows that it is worthwhile to presume that risk aversion is random, because such randomness provides direct answers to the questions raised above.

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1. Introduction

During the past ten years, and specifically since the adoption of the Euro as the official European currency in January 1999, foreign exchange risk has become a frequently voiced concern. There is a widespread sentiment that the volatility of the Euro against the US dollar has destabilized not only the financial markets but also the markets for goods and services. Many economists believe that the strength of the Euro is not warranted by fundamentals, although higher interest rates in the European Union may explain partially the appreciation of the Euro. However the topic of this paper is more about the volatility of the Euro than its strength against the US dollar. The underlying premise is that the foreign exchange risk of the Euro is non-diversifiable, and is therefore systematic or systemic. Systematic risk is the risk that remains when the financial portfolio is well-diversified. It is assumed here that the volatility of the Euro cannot be hedged away, or eliminated, without a social cost.

The procedure followed in this paper borrows from Lucas (1987) who evaluated the cost of removing business cycles by making consumption streams perfectly smooth, or, in other terms, by removing the variability in consumption. See also Ljungqvist and Sargent (2004). Gollier (2001) extends the empirical analysis to US real GDP per capita. The empirical fact is that business cycles do not impose a large cost on consumers. Quite to the contrary, the cost is relatively small, averaging around one tenth of one percent of aggregate demand. The question that is raised here is about the social cost of eliminating the foreign exchange risk of the Euro. This cost is equal to the percent of wealth that the investor is willing to pay to insure against this risk. It is a measure of the risk premium, or the excess return over the risk-less return, which is required by investors to hold the risky Euro currency. It is also the utility that would accrue to investors if this risk is eliminated. Finally, it is the percent of wealth that is needed to compensate investors for bearing such a systematic risk.

By definition systematic risk is exogenous. In the simulations that will be carried out below, the risk of the Euro is taken as given. However, the magnitude of the risk premium and that of the risk-free rate depend both on risk aversion. The business press calls this dependency risk appetite, and the academia calls it investor sentiment. It will be shown that it is worthwhile to assume that the risk-free rate is a random variable that depends on risk aversion, which is itself random. Although economists usually assume that preferences are constant, or, at least, stable, which means that the form of the utility function and the utility parameters, like risk aversion, should not vary, it is assumed in this paper that relative risk aversion varies over time. Since consumer confidence changes frequently over time, as measured by the consumer sentiment index of the University of Michigan, frequent changes in investor sentiment could occur too. This concept is related to Keynes's animal spirits. On the importance of animal spirits for finance see Akerlof and Shiller (2009). The implications of this assumption about risk aversion are twofold. Risk-free yields and risk premiums should be closely related to the degree of risk aversion. Risk-free yields should be negatively related and risk premiums should be positively related to risk aversion. And since foreign exchange risk is exogenous, the total return on the Euro should be independent from risk-free rates over time, whatever the definition of this risk-free rate. Later it will be shown that these two implications hold in the sample.

2. The Theory

The theory is rather straightforward and is formulated in Azar (2010). It is repeated here with minor modifications. The first equilibrium relation is:

$$E\left(U\left(\tilde{W}(1+\theta)\right)\right)=U\left(E\left(\tilde{W}\right)\right) \tag{1}$$

In equation (1) $\tilde{W}$ is the stochastic end-of-period wealth, $E(.)$ is the expectation operator, and $U(.)$ is the utility function. The symbol θ is the proportional upward shift in stochastic wealth that would be required to make the representative investor indifferent between a random systematic shock to wealth, which is the LHS of equation (1), and a non-random allocation of wealth, which is the RHS of equation (1). See Ljungqvist and Sargent (2004: 103). In all applications of equation (1) in this paper, the utility function is assumed to be HARA and isoelastic and of the following form:

$$U(X)=\frac{X^{(1-\gamma)}-1}{(1-\gamma)} \quad for \quad \gamma \neq 1$$
$$and\ U(X)=log(X) \quad for \quad \gamma=1 \tag{2}$$

In equation (2) γ happens to be the coefficient of relative risk aversion (CRRA), sometimes referred to as the elasticity of marginal utility. In addition stochastic wealth is generated by the following process:

$$\tilde{W}=W_0(1+\tilde{r}) \tag{3}$$

In equation (3) W_0 is initial wealth and $\tilde{r}$ is a random realization of the rate of return on the Euro, that will take the following two statistical moments: 5.25755% and 8.73612%. The first term is the total annualized nominal average return on the Euro and the second term is the annualized standard deviation of returns. The sample is monthly from December 1998 to August 2009. The observations on the Euro exchange rate and the Euro interest rate were retrieved from the web page of EconStats before its current reconstruction.

Replacing equation (3) in equation (1) and taking into consideration the functional form in equation (2), the following is obtained:

$$W_0^{(1-\gamma)}E\left(((1+\tilde{r})(1+\theta))^{(1-\gamma)}\right)=W_0^{(1-\gamma)}\left(1+E(\tilde{r})\right)^{(1-\gamma)} \tag{4}$$

The magnitude $W_0^{(1-\gamma)}$ can be eliminated and the term $(1+\theta)^{(1-\gamma)}$ can be factored out. Therefore solving equation (4) for θ one obtains:

$$\theta=\frac{\left[\left(1+E(\tilde{r})\right)^{(1-\gamma)}\right]^{\frac{1}{(1-\gamma)}}}{\left[E\left((1+\tilde{r})^{(1-\gamma)}\right)\right]^{\frac{1}{(1-\gamma)}}}-1=\frac{\left(1+E(\tilde{r})\right)}{\left[E\left((1+\tilde{r})^{(1-\gamma)}\right)\right]^{\frac{1}{(1-\gamma)}}}-1 \tag{5}$$

In case of logarithmic utility, i.e. with $\gamma=1$, equation (5) collapses to the following:

$$log(1+\theta)=log\left(1+E(\tilde{r})\right)-E\left(log(1+\tilde{r})\right) \tag{6}$$

$$or \quad \theta=\frac{\left(1+E(\tilde{r})\right)}{exp\left[E\left(log(1+\tilde{r})\right)\right]}-1 \tag{7}$$

In equation (7) $exp(.)$ is the exponential function. Equation (5) can be written differently as follows:

$$\left[E\left((1+\tilde{r})^{(1-\gamma)}\right)\right]^{\frac{1}{(1-\gamma)}}=\frac{\left(1+E(\tilde{r})\right)}{(1+\theta)} \tag{8}$$

Danthine and Donaldson (2002: 49) and Azar (2008: 54) state another equilibrium relation:

$$E\left(U\left(\tilde{W}\right)\right) = U\left(W_0\left(1 + E(\tilde{r}) - \pi\right)\right) = U\left(W_0\left(1 + rf\right)\right) \quad \Rightarrow$$
$$E\left(\left(1 + \tilde{r}\right)^{(1-\gamma)}\right) = \left(1 + E(\tilde{r}) - \pi\right)^{(1-\gamma)} = \left(1 + rf\right)^{(1-\gamma)} \tag{9}$$

In equations (9) π is the insurance risk premium, and rf is the risk-less return, which is sometimes called the certainty equivalent (Copeland and Weston, 1992: 85-90). Rearranging equation (9) one obtains:

$$\left[E\left(\left(1 + \tilde{r}\right)^{(1-\gamma)}\right)\right]^{\frac{1}{(1-\gamma)}} = \left(1 + rf\right) = \left(1 + E(\tilde{r}) - \pi\right) \tag{10}$$

Solving equation (10) for π one gets:

$$\pi = 1 + E(\tilde{r}) - \left[E\left(\left(1 + \tilde{r}\right)^{(1-\gamma)}\right)\right]^{\frac{1}{(1-\gamma)}} \tag{11}$$

If $\gamma = 1$, the logarithmic counterpart of equation (10) for rf is:

$$rf = 1 - exp\left[E\left(log\left(1 + \tilde{r}\right)\right)\right] \tag{12}$$

And the logarithmic counterpart of equation (11) for π is:

$$\pi = 1 + E(\tilde{r}) - exp\left[E\left(log\left(1 + \tilde{r}\right)\right)\right] \tag{13}$$

Comparing equation (8) to equation (10), one can conclude that the following should hold:

$$\left(1 + E(\tilde{r}) - \pi\right) = \frac{\left(1 + E(\tilde{r})\right)}{\left(1 + \theta\right)} \tag{14}$$

Rearranging equation (14), and solving for θ, one gets:

$$\theta = \frac{\pi}{\left(1 + E(\tilde{r}) - \pi\right)} = \frac{\pi}{\left(1 + rf\right)} \tag{15}$$

Equation (15) also applies to log utility, as can be demonstrated by solving equations (7) and (13).

3. The Monte Carlo Simulations

The paper simulates equation (10), along with its logarithmic counterpart equation (12), in order to find out a measure for rf. And it simulates equation (11), along with its logarithmic counterpart in equation (13), in order to find out measures for π. In equations (11) and (13) $E(\tilde{r})$ is estimated internally from the simulations. Finally the paper simulates equation (15) after estimating rf and π.

These equations have two unknown parameters: the coefficient of relative risk aversion (CRRA, or γ) in the utility function, which is defined by equation (2), and the frequency distribution of the risky systematic return. Already the latter is specified to have a nominal mean of 5.25755%, and a standard deviation of 8.73612%, which are the first two moments of the sample of total Euro returns. The second parameter γ will be taken to equal twenty-four different values, starting from 0.5 to 12, by increments of 0.5. Of course a value of 1 means log utility.

The procedure is as follows. I begin by specifying a CRRA (γ), then I draw 10,000 random observations from a normal distribution with mean 5.25755% and standard deviation 8.73612%. I apply the formulas in equations (10), (11), (12), (13) and (15) to find out figures for rf, π and θ. The next step is to repeat the simulation with another round of 10,000 random normal realizations. This provides second estimates for rf, π, and θ. All in all, 500 different estimates are obtained by repeating the simulations 500 times. Then I specify another CRRA, or γ, and I repeat the drawing of 10,000 random normal realizations 500 times. The result is another sample of size 500 of estimates of rf, π and θ each. The means and standard deviations of these 500 estimates are calculated and tabulated in Table I in function of γ. Since 24 CRRA are assumed, then 24 point estimates and standard errors of rf, π and θ are obtained. Table I reports the results. In addition, in Table I, the actual t-statistics, in parenthesis, for the null hypotheses that the estimates are no different from zero are provided. All these t-statistics reject strongly the null. Hence all estimates are statistically significantly different from zero, even the lowest values.

Table I. Risk aversion, the cost of eliminating systemic risk, and risk-free rates (rf). The cost of eliminating systemic risk is measured by π and θ (see the text). The random realization of the risky return follows a normal distribution with mean 5.25755% and standard deviation 8.73612%. All simulations have 10,000 runs that are repeated 500 times.

CRRA= γ	rf	π	θ
0.5	0.050719 (57.052)	0.001824 (68.830)	0.001736 (68.346)
1.0	0.048936 (55.991)	0.003656 (68.464)	0.003485 (68.066)
1.5	0.047047 (54.897)	0.005503 (69.482)	0.005256 (68.706)
2.0	0.045213 (52.634)	0.007353 (66.845)	0.007035 (65.748)
2.5	0.043342 (48.051)	0.009220 (73.175)	0.008837 (72.434)
3.0	0.041504 (47.379)	0.011075 (66.317)	0.010634 (65.239)
3.5	0.039591 (44.635)	0.012983 (64.915)	0.012489 (64.046)
4.0	0.037710 (40.768)	0.014883 (66.147)	0.014342 (64.896)
4.5	0.035804 (37.257)	0.016763 (66.785)	0.016184 (65.258)
5.0	0.033887 (36.359)	0.018701 (62.130)	0.018088 (60.698)
5.5	0.031934 (32.652)	0.020646 (61.814)	0.020008 (60.084)
6.0	0.030046 (31.039)	0.022549 (62.463)	0.021891 (60.808)
6.5	0.028035 (27.675)	0.024518 (60.389)	0.023849 (58.886)
7.0	0.026100 (26.524)	0.026473 (60.029)	0.025800 (58.371)
7.5	0.024089 (22.450)	0.028457 (60.547)	0.027788 (58.501)
8.0	0.022053 (20.572)	0.030490 (60.858)	0.029833 (58.726)
8.5	0.020226 (18.288)	0.032400 (58.378)	0.031758 (56.209)
9.0	0.018138 (16.414)	0.034436 (55.993)	0.033823 (53.944)
9.5	0.016120 (14.708)	0.036479 (56.122)	0.035901 (54.068)
10.0	0.014071 (12.933)	0.038509 (54.391)	0.037975 (52.524)
10.5	0.011919 (10.240)	0.040614 (49.772)	0.040136 (47.522)
11.0	0.009803 (7.925)	0.042750 (52.778)	0.042336 (50.400)
11.5	0.007847 (6.507)	0.044779 (54.809)	0.044431 (52.395)
12.0	0.005681 (4.259)	0.046828 (47.253)	0.046565 (45.077)

Notes: t-statistics are in parenthesis. The t-statistics are for testing the null hypotheses that the estimates are no different from zero.

The results in Table I have the following patterns. The higher the risk aversion is the lower the risk appetite, or technically, the lower the risk tolerance. A risk aversion of 0.5 produces the highest risk-free yield (5.0719%). A risk aversion of 12 produces the lowest risk-free yield (0.5681%). The higher the risk aversion is the lower the risk-free yield. The lowest γ, which is 0.5, produces a θ of 0.1736% and a π of 0.1824%. The highest γ, which is 12, produces a θ of 4.6565%, and a π of 4.6828%. The higher the risk aversion γ is the higher are both θ and π. The correlation coefficient between θ and π is 0.99993 and is not substantially different from 1. Therefore, depending on the assumption about relative risk aversion, the cost of systematic risk is as low as 0.2% but can be as high as 4.7%. There is reason to believe that 4.7% is the current actual cost. This derives from the fact that lately the interest rate, or the risk-free yield, on the Euro was very low. A figure of 4.7% is indeed substantial. It implies that the social cost of the foreign exchange risk of the Euro is 4.7% of the actual reserves of the Euro in the international financial markets. The cost of eliminating business cycles, which is estimated to be one tenth of one percent of aggregate demand, seems of no consequence compared to the 4.7% cost of removing the Euro systematic risk.

4. The Empirical Regularities

Table I reveals that there is an inverse relation between the risk-free rate rf and risk aversion, and a positive relation between risk aversion and the two costs of systematic risk π and θ. Following Azar (2010) the relations are deemed non-linear. It is natural to assume that risk aversion is the exogenous factor, and that it should be the independent variable. Table II presents the results of regressing the risk-free rate rf, π and θ on the risk aversion parameter.

Table II. Regression analysis between the risk aversion γ, the cost of risk θ, the risk-free rate rf, and the excess return π.

dependent variable $\rightarrow$	θ	π	rf	γ	γ	γ
constant	0.006474 (2.64818)	0.003979 (1.911146)	5.251418 (1719.030)	0.004101 (0.94044)	-0.002253 (-0.50959)	13.33164 (1373.934)
γ	0.340346 (377.708)	0.360599 (469.8521)	-0.359782 (-319.5029)			
$\gamma-square$	0.003927 (56.1158)	0.002452 (41.13482)	-0.002519 (-28.79723)			
θ				2.882503 (679.801)		
$\theta-square$				-0.06635 (-77.147)		
π					2.752828 (650.0769)	
$\pi-square$					-0.040916 (-48.1679)	
rf						-2.316198 (-300.7483)
$rf-square$						-0.042033 (-31.67641)
Adjusted $R-square$	0.999994	0.999995	0.999989	0.999997	0.999997	0.999992

Notes: t-statistics are in parenthesis. The values θ, rf and π are all in percentages. The coefficient of relative risk aversion is γ. The total number of observations per variable in the regression equation is 24.

In what concerns the regression with the risk-free rate (Table II, column 4) the relation is quadratic and negative, as expected, and has a constant of 5.25142%, which is highly significant statistically. This constant identifies the risk-free rate that is consistent with a zero risk aversion, or a π of zero. Theoretically it should be exactly 5.25755%, which is the expected return on the Euro $E(\tilde{r})$, that was assumed in the Monte Carlo simulations. This constant is close to its expected value, but is marginally different from it, with an actual t-statistic of 2.007. This is due to the high precision in the estimate of the constant. Although the sample size is 24 the regression has a very good fit, as measured by the adjusted R-Square. The regressions, with π and θ as dependent variables, have also very good fits. These last two regressions have estimators that are close to each other, are positive and highly significant. Again the regressions are quadratic. All F-test p-values are below 0.00001.

These three regressions allow the investor to find out the risk-free rate and the two costs of systematic risk for a given level of risk aversion. However, in practice, risk aversion is not known in advance. The only variable that can be retrieved from the market is the level of the risk-free rate. From the risk-free rate, the value of π can be computed, because:

$$E(\tilde{r}) - \pi = rf \quad \Rightarrow \quad \pi = E(\tilde{r}) - rf = 0.0525755 - rf \tag{16}$$

Moreover, from rf and π the value of θ can be calculated because:

$$\theta = \frac{\pi}{1 + E(\tilde{r}) - \pi} = \frac{\pi}{1 + rf}$$

which is equation (15) in the text. Based on the above it is more interesting to take the risk aversion as the dependent variable. This is done in Table II (columns 5 to 7).

As expected the fits are very good, and the relations are again quadratic. A zero risk-free rate is consistent with a risk aversion parameter of 13.33. A zero π and a zero θ correspond to a risk aversion of zero, because the two constants are not statistically significant. These three regressions permit the calculation of the risk aversion parameter, if rf, π *and* θ are known. And again, π *and* θ are known if rf is known.

The regressions of θ and π imply maxima of 31.3 and 46.3 for γ respectively. These estimates are too high to be reasonable, and much beyond the sample boundaries. Therefore their values are immaterial. The maximum risk aversion γ is 13.25 and is obtained when the risk-free yield is -0.0363%.

The analysis above that the risk-free rate depends on risk aversion, given the Euro risk, implies that the risk-free rate is a random variable not related to total returns on the Euro. The reason for that is the assumption of changing risk aversion preferences. If these preferences change then risk-free rates will change too according to the estimated regression in Table II (column 4). Utility preferences change, because either risk appetite or investor sentiment change. Hence risk aversion is random and time-variable. Consequently, randomness in risk aversion implies randomness in risk-free rates. And since, in Table I, the frequency distribution of the risky asset produces variable risk-free rates with variable risk aversion then, the risk-free rate depends only on risk aversion and not on the returns on the Euro. Saying that risk-free rates are determined on the demand side by investors does not rule out effects from the supply side, i.e.

monetary policy. However there is reason to believe that interest rate changes by the European Central Bank (ECB) have added to the randomness of the risk-free rate instead of eliminating it. This is true because, over the years, monetary policy has reversed course several times, and may have been the source of the presence of business cycles, or what some economists have called stop-and-go outcomes. Hence a regression of total Euro returns ($\tilde{r}$) on risk-free rates (rf) should be insignificant, with the slope α_1 in the following regression insignificantly different from zero:

$$\tilde{r}_t = \alpha_0 + \alpha_1 rf_t + \varepsilon_t \tag{17}$$

There is an ambiguity in choosing the correct risk-free yield. Should be the interest rate on the Euro or the interest rate on the US dollar? The two will be considered. The data on the monthly Euro foreign exchange rate against the US dollar, the Euro interest rate and the monthly US T-bill rate are retrieved from the web page of EconStats before its current reconstruction. The data span the period from January 1999 to June 2009. The results of the regressions between the Euro total rate of return, as a dependent variable, and the two proxies for the risk-free yield, as separate independent variables, are presented in Table III below. The regressions include an autoregressive variable which picks up non-synchronous trading.

Table III. Regression results with the total return on the Euro as the dependent variable. The Euro rate is defined as US dollars per Euro.

Constant	0.009132 (1.5805)	0.010250 (1.0695)
Monthly 3-month US T-bill rate	-1.800273 (-0.9004)	
Euro interest rate		-2.121776 (-0.6106)
AR(1)	0.292589 (3.4176)	0.298744 (3.5006)
$\overline{R}^2$	0.085033	0.081887
Log likelihood	292.5434	292.4272
Durbin-Watson statistic	1.923268	1.926171
Q(12) p-value Q(24) p-value	0.552 0.829	0.560 0.835
$Q^2(12)$ p-value $Q^2(24)$ p-value	0.040 0.350	0.091 0.474
p-value of the Ramsey RESET test by including the squares and the triples of the fitted variable	0.7737	0.6805
p-value for the maximum Wald F-statistic of the Quandt-Andrews unknown breakpoint test (number of breaks compared is 88)	0.9723	0.8868

Notes: t-statistics in parenthesis. Q(k) is the Ljung-Box Q-statistic for lag k on the residuals. $Q^2(k)$ is the Ljung-Box Q-statistic for lag k on the residuals squared. The number of observations per variable, after adjustments, is 126. The sample starts on January 1999. The reference to the RESET test is Ramsey (1969). The references to the Quandt-Andrews test are Andrews (1993) and Andrews and Ploberger (1994).

In Table III the coefficients α_1, i.e. the slopes, are not only insignificant statistically but they have the wrong negative sign. The econometric diagnostics are all favorable. Therefore there are no problems of higher-order serial correlation and further conditional heteroscedasticity, as measured by the Ljung-Box Q-statistics (Ljung and Box, 1979) on the residuals and the squared residuals. Moreover the Ramsey RESET test rejects specification bias. Finally a search for 88 possible break points in the two regressions failed to reject the absence of breaks. The empirical evidence is strong that there is lack of association between the total return on the Euro and risk-free yields. The frequency distribution of the Euro risk is hence exogenous, and risk-free yields are random as risk aversion is random.

5. Robustness of the results

In order to check for the robustness of the Monte Carlo simulations, a different procedure was implemented, which is bootstrapping. Sampling 500 times a sample of 126 from the actual sample of 126 observations produces 500 estimates for rf, θ and π for each chosen risk aversion parameter. Bootstrapping is repeated with a different value of the risk aversion parameter. As with the Monte Carlo simulation 24 different values for the risk aversion are assumed, starting from 0.5 to 12 in increments of 0.5. The results are presented in Table IV.

Table IV. Results from bootstrapping 500 times the actual sample for each risk aversion parameter. The number of observations per risk aversion is 500.

CRRA= γ	rf	π	θ
0.5	0.049137 (12.598)	0.001878 (53.324)	0.001790 (51.673)
1.0	0.048255 (12.637)	0.003763 (56.923)	0.003590 (55.767)
1.5	0.045452 (11.649)	0.005639 (58.485)	0.005394 (57.671)
2.0	0.043635 (11.169)	0.007543 (53.987)	0.007229 (52.499)
2.5	0.041986 (11.411)	0.009406 (54.947)	0.009029 (53.466)
3.0	0.040068 (10.949)	0.011311 (54.724)	0.010877 (53.069)
3.5	0.038591 (10.527)	0.013202 (54.968)	0.012713 (54.169)
4.0	0.035126 (9.480)	0.015080 (52.554)	0.014572 (50.784)
4.5	0.033962 (9.078)	0.016920 (53.675)	0.016367 (52.352)
5.0	0.033036 (8.634)	0.018826 (52.340)	0.018228 (50.364)
5.5	0.030425 (7.779)	0.020713 (53.150)	0.020107 (50.841)
6.0	0.028503 (7.439)	0.022615 (54.140)	0.021992 (52.721)
6.5	0.027234 (6.636)	0.024528 (52.808)	0.023885 (50.298)
7.0	0.024221 (6.030)	0.026452 (54.968)	0.025835 (51.881)
7.5	0.023001 (6.167)	0.028378 (51.522)	0.027749 (49.044)
8.0	0.020751 (5.217)	0.030111 (56.170)	0.029508 (52.908)
8.5	0.020493 (5.281)	0.031973 (51.804)	0.031341 (49.260)
9.0	0.017404 (4.680)	0.034006 (51.217)	0.033435 (48.870)
9.5	0.015193 (3.995)	0.035740 (52.483)	0.035216 (49.902)
10.0	0.013064 (3.431)	0.037836 (50.979)	0.037361 (48.382)
10.5	0.011495 (2.995)	0.039515 (48.182)	0.039082 (45.416)
11.0	0.009143 (2.454)	0.041616 (53.532)	0.041251 (50.962)
11.5	0.008071 (2.111)	0.043331 (53.285)	0.043001 (49.736)
12.0	0.006369 (1.665)	0.045415 (53.749)	0.045142 (50.788)

Note: t-statistics in parenthesis. The t-statistics test the null hypothesis that the variable has a zero mean.

In Table IV all values are statistically significantly different from zero except the risk-free yield of 0.637% with a risk aversion coefficient of 12. Table II predicts a risk-free yield of 0.904% for a risk aversion of 12. The difference between the two estimates is small. A cursory look at Tables I and Table IV shows that the estimates are close to each other. Therefore all the patterns found in Table I apply to Table IV. Nonetheless further scrutiny finds a bias between the estimates in Table I and Table IV. The bias is found by regressing the values in Table I on their corresponding values in Table IV. The results are shown in Table V.

Table V. Regressions between the values in Table I and their corresponding values in Table IV.

Dependent variable $\rightarrow$	rf (*Table* 1)	π (*Table* 1)	θ (*Table* 1)
Constant	0.000127 (0.4428)	-0.000592 (-5.2605)	-0.000589 (-5.1927)
rf (*Table* 4)	1.033313 (109.944)		
π (*Table* 4)		1.035879 (248.124)	
θ (*Table* 4)			1.035368 (242.211)
p-value of the null hypothesis: slope = 1	0.0018	< 0.0001	< 0.0001
$\overline{R}^2$	0.998101	0.999627	0.999608

Notes: t-statistics in parenthesis. The values θ, rf and π are all in percentages. The total number of observations per variable in each regression equation is 24.

An absence of bias means that he expected values of the constants are zero, and those of the slopes are 1. The constant is statistically insignificantly different from zero for the first regression, that of the two risk-free yields rf. The constants of the other two regressions are statistically significant but they take very small values -0.000592% and -0.000589% respectively. Their economic significance is hence very low. What is disturbing is that all the slopes are statistically significantly different from 1 at very low marginal significance levels. But again the bias from 1 is economically small, with a maximum bias from 1 of 0.036. One can conclude that *economically* the bias is small. The two sampling procedures, by Monte Carlo simulation and by bootstrapping, seem to give consistent results. These results are hence robust.

6. Conclusion

This paper starts from expected utility analysis and from the assumption that the return on the risky asset is given and is exogenous. Then by changing risk aversion, the cost of eliminating the systematic risk of the Euro is estimated. This cost varies between 0.18% for a risk aversion parameter of 0.5 to 4.68% for a risk aversion parameter of 12. I argue that the latter figure of 4.68% is the more accurate.

Then the relations between the costs of risk, risk-free yields, and risk aversion are estimated by regression analysis. Two sets of regressions are carried out. One set is with the risk aversion parameter as the independent variable, and the other set with the risk aversion parameter as the dependent variable. The fit of all regressions is impeccable. Since the risk aversion is not available in the real world I argue to take the market risk-free yield, and from it calculate the level of risk aversion and the costs of risk.

The relation between The Euro total returns and risk-free yields is estimated. The theory predicts that there should not be any statistically significant relation between the two, because risk-free yields are determined by random risk aversion which makes these yields random themselves, while the risky return is given. The regression is carried out with two different specifications of the risk-free yield, and they both result in failing to reject independence between stock returns and risk-free yields.

Finally a different resampling procedure is implemented that of bootstrapping. Always there is evidence of statistical bias the general conclusion is that the bias is economically very small, meaning that the results are robust.

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