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Exchange Risk Premia with the Intertemporal, International Asset Pricing Model: An Econometric Analysis *

by

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Abstract

This paper considers a model which admits the existence of risk premia for spot foreign exchange. To maximize his or her lifetime utility, a representative agent of each of four major countries who may have heterogeneous taste allocates his or her wealth to domestic money used for consumption and various currency-denominated securities according to expected returns measured in domestic currency. The general, risk-neutral and static asset pricing specifications are each tested by techniques proposed by Hansen (1982) and Newey and West (1987b). Some favorable results for the existence of risk premia and the intertemporal asset pricing model are obtained.

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1.Introduction

Both theoretical and empirical research of exchange rate determination have been popular since the early 1980s. This research has one important feature, the existence of risk premia. The imperfect substitutability of domestic and foreign securities due to their different currency denominations implies that the interest rate differential is equal to the expected change in the exchange rate, plus a risk premium. The short-run equilibrium describes the allocation of a given stock of wealth among demestic money, domestic security, and foreign securities according to the expected returns, and exchange rates are determined with other asset prices on all financial markets including money markets.

Research concerned mainly with risk premia and asset pricing has proceeded along two lines. Along the first line which is closely related to the asset market approach, demand and supply equilibrium conditions of asset markets are specified while along the second line an equilibrium asset pricing relationship is derived from a representative agent's intertemporal optimization behavior. Along the first line there is one branch where asset demand functions are postulated in structural form and a second branch where they are given by a static asset pricing model.

Theoretical research utilizing structural asset demand functions was discussed by W.H. Branson and D.W. Henderson (1985). There has been a good deal of empirical research along this line including M. Obstfeld (1983) and K.K. Lewis (1988).

F.L.A. Grauer *et.al* (1976) derived a static asset pricing model to explain foreign exchange risk. Empirical investigations of the model in which an agent optimizes by the mean-variance approach have been conducted by R. Roll and B.H. Solnik (1977), J. Frankel and C.M. Engel (1984), S.W. Black and M.K. Salemi (1988), and T. Serita (1991).

Finally, theoretical analyses using the intertemporal asset pricing model have been presented by B.H. Solnik (1974) and R. Lucas, Jr (1982). Empirical tests of models which generate risk premia in the forward foregin exchange market have been reported by L.P., Hansen and R.J., Hodrick (1983), R.J. Hodrick and S. Srivastava (1984), N.C. Mark (1985), R.D. Huang (1989), G. Kaminsky and R. Peruga (1990) , and B. Modjahedi (1991).

The empirical research cited above with some exceptions generally contains no support for the existence of risk premia.[1] In each case, asset demand functions or risk premia were not well estimated, over-identifying restrictions were rejected, or hypothesis of risk neutrality was not rejected.[2]

In this paper, a model which implies risk premia of spot foreign exchange is formulated in the framework of an intertemporal, international asset pricing model.[3] In this model, there is a representative agent for each of four major countries (Germany, Japan, U.K. and U.S.A.). Each agent, who may have heterogeneous taste, allocates his or her wealth to either domestic money

[1]Some studies have contradictory results, for example, Black and Salemi (1988), Hansen and Hodrick (1983), Mark (1985) and Modjahedi (1991). On the other hand, Huang (1989) and Serita (1991) showed favorable results for risk premia.

[2]Imperfect substitutability of different currency-denominated assets will not hold when agents are risk neutral.

[3]The general equilibrium of asset markets is not considered explicitly.

used for consumption, or to various currency-denominated securities according to expected returns measured in each domestic currency.

Utilizing only monetary data, the model parameters are estimated and the over-identifying restrictions are tested by the distribution-free generalized method of moments (GMM) technique proposed by L.P. Hansen (1982). Both the risk neutral and the static asset pricing specifications represented by the agent's taste are tested by W.H. Newey and K.D. Wests' (1987b) statistics. As a whole, the result shows some favorable evidence of risk premia in the foreign exchange market and the intertemporal asset pricing model.

For an empirical test of risk premia in the spot foreign exchange market this may be the first study with the following aspect: the intertemporal asset pricing model is utilized and a model allowing heterogeneous agents is formulated in a multicountry setting.

In section 2 we specify the model and the result is shown in section 3. Section 4 concludes the paper. Appendix A displays some test results and the data which we use is described in Appendix B.

2. Model and Agent's Optimization Problem

There is a representative agent in each of the four countries. Agents may have different tastes, but are assumed to have the same set of information. Each maximizes

$$E_0[\sum_{t=0}^{\infty} \beta_i^t U_i(\frac{C_t^i}{P_t^i})], \qquad i = g, jp, uk \quad and \quad us, \qquad (1)$$

where

$U_i(\cdot)$: the utility function of agent i,

β_i: the subjective discount factor of agent i and $0 < \beta_i < 1$,

C_t^i: the nominal consumption at time t of agent i,

P_t^i: the price level at time t of country i,

$E_0 \equiv E[\cdot \mid I_0]$: the expectation operator conditioned on the information set at time zero,

and *g,jp,uk* and *us* are respectively the abbreviations of Germany, Japan, United Kingdom and U.S.A..[4]

Each agent is assumed to allocate his or her wealth among domestic money and various currency-denominated securities of three month maturity according to expected return measured in domestic currency. The domestic money is used for consumption and the returns to the securities are measured in domestic currency.[5]

The maximization of (1) is subject to the following constraints:

$$M_t^i + \sum_{j \in \Lambda_1} q_t^j N_t^{i,j} e_t^{i,j} = \sum_{j \in \Lambda_1} q_{t-3}^j N_{t-3}^{i,j} e_t^{i,j} (1 + {}_{t-3}R_t^j) + (M_{t-1}^i - C_{t-1}^i) + Y_t^i, \quad (2.1)$$

[4]Epstein and Zin (1991) investigated empirically a generalization of conventional, time-additive expected utility. Its formulation was not adopted in this study because it requires the market portfolio and its empirical identification is troublesome. Roll (1977) criticized this point.

[5]There are two main lines to incorporate money into a macroeconomic model: the cash-in-advance constraint and money in the utility function. The first approach is chosen since the monthly consumption data of four countries cannot be obtained.

$$M_t^i \geq C_t^i, \qquad i = g, \cdots, us, \qquad (2.2)$$

where

$\Lambda_1 \equiv \{g, jp, uk, us\}$,

q_t^j: the price of jth currency-denominated security at time t,

$N_t^{i,j}$: the agent i's demand for jth currency-denominated security at time t,

$e_t^{i,j}$: the spot price of currency j in terms of currency i at time t,

$\forall t, i \quad e_t^{i,i} \equiv 1$,

M_t^i: the agent i's demand for domestic money at time t,

Y_t^i: the agent i's non-financial income at time t,

and ${}_{t-3}R_t^j$: the nomial interest rate of the jth currency-denominated security bought at time $t-3$ to mature at time t and the one which can be regarded as a representative interest rate of the jth country's money market.[6][7]

Domestic and foreign securities are considered to be the same with respect to maturity and risk, there are no capital controls and no transaction costs. The only risk is due to uncertainties concerning to the expected exchange rates.

[6]This study considers the aggregated rather than per capita variables because even the quarterly population data of four countries are difficult to obtain. In the case of power utility function, the final aggregated asset demand functions derived by intertemporal optimization is the same regardless of per capita or aggregated formulation. Hakansson (1970) derived various asset demand functions from intertemporal context.

[7]In this model Y_t^i is assumed to be uncontrollable by the representative agent.

We make two additional assumptions. First we suppose that at every time, at least one security has a positive nominal yield. Then the cash-in-advance constraint will be binding in equilibrium. Second we assume utility functions of the form

$$U_i(\frac{C_t^i}{P_t^i}) = \frac{\alpha_i}{1-\phi_i}[(\frac{C_t^i}{P_t^i})^{1-\phi_i} - 1], \qquad i = g, \cdots, us,$$

where

$\alpha_i > 0$ and $\phi_i \geq 0$.[8]

These are power utility with constant risk aversion equal to ϕ_i. $\phi_i > 0$ implies risk aversion and $\phi_i = 0$ implies risk neutrarity. As ϕ_i converges to unity, the power utility function converges to the logarithmic utility function. The intertemporal asset pricing model with logarithmic utility reduces to the static Sharp-Lintner-Mossin asset pricing model.[9]

After some manipulation, the first-order necessary conditions for the above constrained maximization problem are derived;

$$E_t[\beta_i^3(\frac{\frac{M_{t+3}^i}{P_{t+3}^i}}{\frac{M_t^i}{P_t^i}})^{-\phi_i}\frac{P_t^i}{P_{t+3}^i}(1 + {}_tR_{t+3}^i) - 1] = 0,$$

$$E_t[\beta_i^3(\frac{\frac{M_{t+3}^i}{P_{t+3}^i}}{\frac{M_t^i}{P_t^i}})^{-\phi_i}\frac{P_t^i}{P_{t+3}^i}\frac{e_{t+3}^{i,j}}{e_t^{i,j}}(1 + {}_tR_{t+3}^j) - 1] = 0,$$

$$i = g, \cdots, us,\ j \neq i \text{ and } t = 0, 1, 2, \cdots. \qquad (3)$$

[8] $\phi_i = 0$ is not excluded *a priori* because its case is tested in this study.

[9] This is discussed in Hakanson (1970 and 1971) and Giovannini and Weil (1989).

These Euler equations indicate the equilibrium pricing relationship between the interest rates and the exchange rates. Mathematically, these equations represent the orthogonarity conditions between the vector of variables included in the information set I_t and $v_{t,t+3}$ where $E_t[v_{t,t+3}]$.

In the section below we will test whether the model specification including rational expectations is consistent with the actual data. If the model specification is not rejected and it implies risk aversion, the result will be favorable for the foreign exchange risk premia. In addition if it does not reduce to the static asset pricing model, the intertemporal optimization will be justified as a means of deriving the equilibrium asset pricing relationship.

3. Estimation, Test and Results

3.1 Estimation and test

The estimation and the test of the Euler equations (3) are performed by Hansen's (1982) proposed GMM which is called the Hansen's J test. The GMM technique only requires that the variables which appear in the orthogonarity conditions to be stationary and ergodic. Some advantages of this method are that neither the specification of the entire economic environment nor that of the variable's distribution is needed.[10]

To implement GMM technique it is necessary to identify a set of instruments, $z_t \subseteq I_t$. In choosing the instruments, we must take care of the

[10] Hasnen and Singleton (1982) and Ogaki (1992) explained GMM and gave practical guidance.

assumption that the each agent has the same information set and empirical facts of studies utilizing the GMM, *for example*, Mark (1985) and Modjahedi (1991) which reported contradictory results by difference of instruments.

Because we have little guidance in picking up instruments, the lagged variables which appear in the Euler equations are chosen. We assume that each agent knows the real money supply growth rates of all countries and the real rate of each four security's return mesured in domestic and foreign currencies.

Three groups sre considered as z_t. The first group has a constant, the real rate of the domestic security's return measured in the own currency and the dollar exchange rates;

$$Inst1 \equiv \{1, \frac{P^g_{t-3}}{P^g_t}(1+{}_{t-3}R^g_t), \frac{e^{g,us}_t}{e^{g,us}_{t-3}}\}, \qquad Inst2 \equiv \{1, \frac{P^{jp}_{t-3}}{P^{jp}_t}(1+{}_{t-3}R^{jp}_t), \frac{e^{jp,us}_t}{e^{jp,us}_{t-3}}\},$$

$$Inst3 \equiv \{1, \frac{P^{uk}_{t-3}}{P^{uk}_t}(1+{}_{t-3}R^{uk}_t), \frac{e^{uk,us}_t}{e^{uk,us}_{t-3}}\}, \qquad Inst4 \equiv \{1, \frac{P^{us}_{t-3}}{P^{us}_t}(1+{}_{t-3}R^{us}_t), \frac{e^{us,g}_t}{e^{us,g}_{t-3}}\}.$$

The second group adds the money supply growth rate;

$$Inst5 \equiv \{1, \frac{\frac{M^g_t}{P^g_t}}{\frac{M^g_{t-3}}{P^g_{t-3}}}, \frac{P^g_{t-3}}{P^g_t}(1+{}_{t-3}R^g_t), \frac{e^{g,us}_t}{e^{g,us}_{t-3}}\},$$

$$Inst6 \equiv \{1, \frac{\frac{M^{jp}_t}{P^{jp}_t}}{\frac{M^{jp}_{t-3}}{P^{jp}_{t-3}}}, \frac{P^{jp}_{t-3}}{P^{jp}_t}(1+{}_{t-3}R^{jp}_t), \frac{e^{jp,us}_t}{e^{jp,us}_{t-3}}\},$$

$$Inst7 \equiv \{1, \frac{\frac{M^{uk}_t}{P^{uk}_t}}{\frac{M^{uk}_{t-3}}{P^{uk}_{t-3}}}, \frac{P^{uk}_{t-3}}{P^{uk}_t}(1+{}_{t-3}R^{uk}_t), \frac{e^{uk,us}_t}{e^{uk,us}_{t-3}}\},$$

$$Inst8 \equiv \{1, \frac{\frac{M^{us}_t}{P^{us}_t}}{\frac{M^{us}_{t-3}}{P^{us}_{t-3}}}, \frac{P^{us}_{t-3}}{P^{us}_t}(1+{}_{t-3}R^{us}_t), \frac{e^{us,g}_t}{e^{us,g}_{t-3}}\}.$$

The last group has the dollar exchange rates;

$Inst9 \equiv \{1, \frac{e_t^{g,us}}{e_{t-3}^{g,us}}, \frac{e_t^{jp,us}}{e_{t-3}^{jp,us}}, \frac{e_t^{uk,us}}{e_{t-3}^{uk,us}}\}.$

Next, the hypothesis testing of risk neutrarity and that of the static asset pricing model are described respectively as follows;

$$H_1: \quad \phi_i = 0, \quad .versus. \quad A_1: \quad \phi_i \neq 0, \tag{4.1}$$

$$H_2: \quad \phi_i = 1, \quad .versus. \quad A_2: \quad \phi_i \neq 1, \qquad i = g, \cdots, us. \tag{4.2}$$

Each of the null hypotheses H_1 and H_2 implies the perfect substitutability of domestic and foreign assets and the static optimization behavior and each is tested by the D which is similar to the likelihood ratio and the Wald statistic proposed by Newey and West (1987b). Because the estimation of the Euler equations (3) with $\phi_i = 1$ did not converge for many instruments, the Wald test was employed although it may has low power in small samples.[11]

Before examining the results, we briefly review a computer program for GMM estimation. Numerical minimization of the distance function was accomplished with the Gauss-Newton algorithm of the Time Series Processor (TSP) computer package. At the initial value of weighting matrix, nonlinear three stage least squares estimates were used. Conditional heteroscedasticity of disturbance was allowed and the each Bartlett and Parzen kernel proposed by Newey and West (1987a) and Gallant (1987) respectively was examined. The parameter β_i^3 was replaced by $\frac{\theta_i}{(1+|\theta_i|)}$ and ϕ_i was restricted to be nonnegative.[12]

[11]Modjahedi (1991) made use of the D statistic to test risk neutrarity. Newey and West (1987b) provided also the score and the minimum chi-square statistics. The score statistic can not be utilized to test risk neutrarity because it requires zero division.

[12]Though β_i was restricted only within unit circle, it was confirmed that estimates of

3.2. Results

We consider the period t of the Euler equations (3) to be from December 1980 through December 1988. The starting period corresponds to the revision of 'Foreign Exchange and Foreign Trade Control Law' in Japan. This revision allowed an investor to deal with a foreign exchange freely. The last period corresponds to the availability of data.[13]

Because some variables before period t are needed for the estimation, the sample period was chosen to be September 1980 through December 1988. The data was taken monthly, and is described in Appendix B. The seasonally adjusted data of money supply and price level were utilized to avoid nonstationarity due to seasonality.[14] The price level of each country was seasonally adjusted by the X11 procedure which is contained in the Statistical Analysis System (SAS).

The Euler equations (3) are estimated and tested for each country.[15]

The Euler equations of all countries are not simultaneously estimated

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θ_i on the iterative process took only strictly positive values, *that is*, β_i can be restricted actually from zero to unity. It was difficult to get the convergence with an *a priori* restriction $0 < \beta_i < 1$ for some instruments.

[13]Thereafter some consistent time series data was not available.

[14]The stationarity of the variables, $\frac{\frac{M^i_{t+3}}{P^i_{t+3}}}{\frac{M^i_t}{P^i_t}}$, $\frac{P^i_t}{P^i_{t+3}}(1 + {}_tR^i_{t+3})$, $\frac{P^i_t}{P^i_{t+3}}\frac{e^{i,j}_{t+3}}{e^{i,j}_t}(1 + {}_tR^j_{t+3})$, $(\frac{e^{i,j}_{t+3}}{e^{i,j}_t}$ and $\frac{P^i_t}{P^i_{t+3}}(\frac{e^{i,j}_{t+3}}{e^{i,j}_t}(1 + {}_tR^j_{t+3}) - (1 + {}_tR^i_{t+3}))$ was ascertained by ploting the auto and the patial auto correlation and the augmented Dicky-Fuller test of a single unit root. The Dicky-Fuller test results are available from the author upon request.

[15]Because the estimation of the form (3) did not converge in many cases, the Euler equations of countries other than U.S. were rewritten as the following form;

because of the difficulty of convergence in estimation and L.P. Hansen and K.J. Singleton (1982) stated that using more orthogonarity conditions may lead to estimators with less desirable small sample properties.

The results are reported in the tables for each country. Table 2.g and Table 2.jp are shown in this section and Appendix A displays Table 2.uk and 2.us.

$$E_t[\beta_i^3(\frac{\frac{M_{t+3}^i}{P_{t+3}^i}}{\frac{M_t^i}{P_t^i}})^{-\phi_i}\frac{P_t^i}{P_{t+3}^i}(1+{}_tR_{t+3}^i)-1]=0,$$

$$E_t[(\frac{\frac{M_{t+3}^i}{P_{t+3}^i}}{\frac{M_t^i}{P_t^{us}}})^{-\phi_i}\frac{P_t^i}{P_{t+3}^i}(\frac{e_{t+3}^{i,j}}{e_t^{i,j}}(1+{}_tR_{t+3}^j)-(1+{}_tR_{t+3}^i))]=0, \quad i=g,jp \quad and \quad uk.$$

Table 2.g Estimation results : German agent's case

inst	*k*	$\hat{\beta}_g$	$s.e.(\hat{\theta}_g)$	$\hat{\phi}_g$	$s.e.(\hat{\phi}_g)$	$Jtest(d.f.)$	$Pvalue$	D_g	W_g
*Inst*1	B	0.998	18.835	0.205	0.047	15.195(10)	0.125	20.503**	291.627**
*Inst*2	B	0.998	16.364	0.117	0.051	6.932(10)	0.732	5.690*	295.866**
*Inst*3	B	0.998	12.036	0.044	0.041	12.591(10)	0.247	1.129	535.368**
*Inst*4	B	0.998	19.617	0.191	0.054	11.118(10)	0.348	12.460**	225.148**
*Inst*5	B	0.998	14.282	0.101	0.035	22.083(14)	0.077	8.627**	668.297**
*Inst*6	B	0.998	13.113	0.073	0.037	13.351(14)	0.499	4.214*	639.587**
*Inst*7	B	0.998	12.847	0.071	0.041	16.382(14)	0.291	3.043	518.260**
*Inst*8	B	0.998	15.471	0.136	0.031	16.451(14)	0.287	20.548**	782.189**
*Inst*9	B	0.998	19.679	0.216	0.039	14.773(14)	0.394	31.505**	414.269**
*Inst*1	P	0.998	18.649	0.206	0.043	16.571(10)	0.084	23.571**	333.474**
*Inst*2	P	0.998	15.938	0.110	0.050	7.973(10)	0.632	5.313*	316.359**
*Inst*3	P	0.998	12.001	0.044	0.040	13.606(10)	0.192	1.215	567.166**
*Inst*4	P	0.998	19.407	0.188	0.051	13.449(10)	0.200	13.371**	251.528**
*Inst*5	P	0.998	14.372	0.097	0.034	26.141(14)	0.025*	8.151**	697.504**
*Inst*6	P	0.998	13.689	0.072	0.039	14.773(14)	0.394	3.654	555.369**
*Inst*7	P	0.998	12.738	0.071	0.040	18.786(14)	0.173	3.237	552.853**
*Inst*8	P	0.998	15.455	0.134	0.031	19.805(14)	0.136	19.809**	775.913**
*Inst*9	P	0.998	18.628	0.208	0.039	17.309(14)	0.240	28.052**	404.543**

Table 2.jp Estimation results : Japanese. agent's case

$inst$	k	$\hat{\beta}_{jp}$	$s.e.(\hat{\theta}_{jp})$	$\hat{\phi}_{jp}$	$s.e.(\hat{\phi}_{jp})$	$Jtest(d.f.)$	$Pvalue$	D_{jp}	W_{jp}
$Inst1$	B	0.998	59.816	0.341	0.212	15.460(10)	0.116	2.810	9.698**
$Inst2$	B	0.997	24.631	0.169	0.115	6.600(10)	0.763	2.173	52.120**
$Inst3$	B	0.998	139.392	0.485	0.325	10.978(10)	0.359	3.456	2.512
$Inst4$	B	0.997	17.748	0.070	0.128	13.147(10)	0.216	0.397	52.851**
$Inst5$	B	0.998	78.973	0.387	0.239	18.407(14)	0.189	2.814	6.572*
$Inst6$	B	0.997	6.700	0.007	0.041	15.555(14)	0.341	0.059	586.084**
$Inst7$	B	0.998	37.483	0.265	0.143	15.897(14)	0.320	4.636*	26.553**
$Inst8$	B	0.997	182.273	0.070	0.129	15.154(14)	0.368	0.487	51.875**
$Inst9$	B	0.998	30.810	0.275	0.121	11.945(14)	0.611	6.923**	35.892**
$Inst1$	P	0.998	49.259	0.284	0.217	16.799(10)	0.079	2.041	10.853**
$Inst2$	P	0.997	24.301	0.168	0.116	7.495(10)	0.678	2.130	51.775**
$Inst3$	P	0.998	112.087	0.422	0.329	12.045(10)	0.282	2.720	3.081
$Inst4$	P	0.997	17.464	0.072	0.127	15.602(10)	0.112	0.438	53.067**
$Inst5$	P	0.998	64.166	0.328	0.246	21.432(14)	0.091	2.038	7.485**
$Inst6$	P	0.997	6.622	0.004	0.042	17.289(14)	0.241	0.059	559.927**
$Inst7$	P	0.998	34.089	0.232	0.147	17.380(14)	0.236	3.381	27.210**
$Inst8$	P	0.997	17.756	0.053	0.133	17.842(14)	0.214	0.374	51.086**
$Inst9$	P	0.998	30.575	0.275	0.123	14.144(14)	0.439	6.887**	34.738**

Note: The sampl size is 94, *inst* is the abbreviation of instruments, k, B and P are respectively the abbreviations of kernel, Bartlett and Parzen, the hatted parameter indicates the estimate, $s.e.(\cdot)$ is the asymptotic standard error of the estimate, β_i is equal to $(\frac{\theta_i}{(1+|\theta_i|)})^{1/3}$ which the reader may refer to section 3.1, *Jtest* reports the value of statistic which follows a χ^2 distribution asymptotically with $d.f.$ degrees of freedom under the null hypothesis that the Euler equations

(3) hold, *Pvalue* is the one of *Jtest*, each D_i and W_i is the value of D and Wald statistic which tests the hypothesis (4.1) and (4.2) and follows a χ^2 distribution asymptotically with 1 degree of freedom under the null hypothesis that $\phi_i = 0$ and $\phi_i = 1$ holds respectively, and each one of $*$ and $**$ represents the rejection at the upper 5 and 1 % siginificance level respectively.

Constrained estimation with $0 < \beta_i < 1$ and nonnegative ϕ_i worked well for almost all instruments.[16]

The main conclusion did not change by the difference of kernel.

The general specification of our model was rejected at the 5% significance level for only one case, *Inst*5 of German agent when the Parzen kernel was utilized. This may indicate that the Euler equations (3) hold. The $P-value$ of each agent's *Jtest* varies considerably and was affected by the instruments, *for example*, the $P-value$ of *Inst*2 was larger than the ones of *Inst*1, *Inst*3 and *Inst*4.

The almost estimates of θ_i were significantly not equal to zero at the 5% significance level although the ones of not θ_i but β_i were shown. The estimates of the subjective discount factor ranged from 0.996 to 0.999 and were scarcely affected by the instruments.[17] The estimates of German and U.K., $\hat{\beta}_g$ and $\hat{\beta}_{uk}$ were relatively larger than the ones of Japanese and U.S.,

[16]In the each *Inst*2 and *Inst*6 case of U.S. agent, ϕ_{us} was set to zero *a priori*.

[17]Kocherlakota (1990) showed that well-defined competitive equilibria with positive interest rates may exist in infinite growth economies even though individuals have discount factors larger than one. Unconstrained estimation of β_i was conducted in this model. The results were similar to the ones with $0 < \beta_i < 1$.

$\hat{\beta}_{us}$ and $\hat{\beta}_{jp}$.

On the other hand, the estimates of ϕ_i were scattered between 0 and 0.5. These values may be inside the plausible range, because according to R. Prescott and E.C. Mehra (1985), a power parameter in an equilibrium asset pricing model should be in the range from zero to two.

The hypothesis of risk neutrarity was rejected generally at the 5% significance level except for Japan. When the variables of Japan were utilized as the instruments, *that is,* the each *Inst*2 and *Inst*6 case, the converged estimate of ϕ_{us} was not obtained under the alternative although more than half cases were rejected at the 5% significance level for the U.S. agent case. Three and four cases utilizing each kernel were rejected at the 10% significance level for the Japanese case. When the exchange rates were taken as the instruments, *that is, Inst9* case, any ϕ_i was significantly above zero. We may recognize the foreign exchange risk premia and the risk averseness of agents although the question of the uniqueness of the Japanese case remains.[18]

Last, the static asset pricing specification was rejected decisively for almost all instruments. Because it was proved that ϕ_i is significantly different from unity, intertemporality of optimization was justified in this model.

4. Concluding Remarks

We consider three possible reasons for the favorable results with respect to the existence of risk premia which we have obtained.

[18]According to Otani (1993), when an agent is risk averse, we can obtain properties of portfolio demand in the portfolio choice problem arising in general equilibrium with financial assets.

One is the multicountry setting. Because the exchange rates of the major four currencies are correlated strongly, the simultaneity of exchange rates determination may be important. Next is the allowance of heterogeneous agents. The assumption of homogeneity may be rather restrictive although it was not tested. Last is the relatively short sample periods compared to the usual intertemporal asset pricing studies. The longer the sample period is, the more volatile are the movements of asset prices which the model should explain.

The heterogeneity of agents which was allowed in this study should be tested. The uniquness of the Japanese agent which was indicated in section 3.2 remains unexplained. It will remain for our future research to consider a general equilibrium condition of our model which can be analyzed empirically.

Appendix A: Table 2.uk Estimation results : U.K. agent's case

inst	k	$\hat{\beta}_{uk}$	$s.e.(\hat{\theta}_{uk})$	$\hat{\phi}_{uk}$	$s.e.(\hat{\phi}_{uk})$	$Jtest(d.f.)$	$Pvalue$	D_{uk}	W_{uk}
*Inst*1	B	0.999	131.522	0.300	0.049	15.465(10)	0.116	38.790**	201.934**
*Inst*2	B	0.998	36.433	0.165	0.041	7.506(10)	0.677	16.306**	409.581**
*Inst*3	B	0.999	138.328	0.287	0.075	12.804(10)	0.235	16.770**	90.031**
*Inst*4	B	0.999	162.485	0.284	0.052	9.364(10)	0.498	30.045**	190.901**
*Inst*5	B	0.999	186.424	0.320	0.047	20.300(14)	0.121	46.358**	206.219**
*Inst*6	B	0.998	36.786	0.178	0.040	13.107(14)	0.518	19.994**	413.978**
*Inst*7	B	0.998	28.443	0.163	0.033	16.309(14)	0.295	27.240**	626.345**
*Inst*8	B	0.999	114.890	0.285	0.051	14.086(14)	0.443	35.427**	194.500**
*Inst*9	B	0.998	79.816	0.275	0.046	14.094(14)	0.443	39.437**	245.730**
*Inst*1	P	0.999	127.115	0.293	0.053	16.891(10)	0.077	30.702**	176.730**
*Inst*2	P	0.998	35.619	0.166	0.041	8.334(10)	0.596	16.367**	404.978**
*Inst*3	P	0.999	138.038	0.286	0.073	13.925(10)	0.176	17.336**	95.606**
*Inst*4	P	0.999	170.471	0.283	0.055	10.983(10)	0.359	26.544**	171.095**
*Inst*5	P	0.999	187.505	0.308	0.052	23.614(14)	0.051	34.595**	173.882**
*Inst*6	P	0.998	36.719	0.178	0.040	14.280(14)	0.429	19.769**	414.123**
*Inst*7	P	0.998	27.975	0.166	0.033	18.935(14)	0.167	27.680**	638.347**
*Inst*8	P	0.999	109.649	0.275	0.055	16.498(14)	0.284	28.749**	176.588**
*Inst*9	P	0.998	78.371	0.275	0.049	16.378(14)	0.291	34.449**	222.351**

Table 2.us Estimation results : U.S. agent's case

$inst$	k	$\hat{\beta}_{us}$	$s.e.(\hat{\theta}_{us})$	$\hat{\phi}_{us}$	$s.e.(\hat{\phi}_{us})$	$Jtest(d.f.)$	$Pvalue$	D_{us}	W_{us}
$Inst1$	B	0.997	15.194	0.255	0.115	15.659(10)	0.110	5.193*	41.939**
$Inst2$	B	0.996	6.640	0	\	7.372(10)	0.690	0	\
$Inst3$	B	0.997	11.125	0.135	0.092	10.713(10)	0.380	2.334	87.460**
$Inst4$	B	0.997	11.411	0.173	0.084	10.673(10)	0.384	4.518*	96.301**
$Inst5$	B	0.997	11.881	0.236	0.106	20.037(14)	0.129	7.681**	52.139**
$Inst6$	B	0.996	5.998	0	\	16.438(14)	0.287	0	\
$Inst7$	B	0.997	6.798	0.056	0.067	14.863(14)	0.388	0.992	198.916**
$Inst8$	B	0.997	12.346	0.266	0.088	15.834(14)	0.324	9.801**	69.856**
$Inst9$	B	0.997	11.939	0.227	0.078	13.936(14)	0.455	9.172**	99.394**
$Inst1$	P	0.997	14.599	0.229	0.112	17.652(10)	0.061	4.649*	47.370**
$Inst2$	P	0.996	6.339	0	\	8.566(10)	0.574	0	\
$Inst3$	P	0.997	10.565	0.116	0.088	11.759(10)	0.302	1.851	100.099**
$Inst4$	P	0.997	11.663	0.167	0.082	12.682(10)	0.242	4.507*	103.652**
$Inst5$	P	0.997	11.564	0.204	0.101	23.455(14)	0.053	7.737**	61.556**
$Inst6$	P	0.996	5.798	0	\	19.065(14)	0.162	0	\
$Inst7$	P	0.996	6.834	0.036	0.065	16.891(14)	0.262	0.652	216.856**
$Inst8$	P	0.997	11.809	0.237	0.087	18.885(14)	0.169	7.866**	77.479**
$Inst9$	P	0.997	11.491	0.202	0.080	16.433(14)	0.288	6.845**	98.447**

Note: The reader may see footnote 16 with respect to the each $Inst2$ and $Inst6$ case of U.S. agent, the sample size is 94, $inst$ is the abbreviation of instruments, k, B and P are respectively the abbreviations of kernel, Bartlett and Parzen, the hatted parameter indicates the estimate, $s.e.(\cdot)$ is the asymptotic standard error of the estimate, β_i is equal to $(\frac{\theta_i}{(1+|\theta_i|)})^{1/3}$ which the reader may refer to section 3.1, $Jtest$ reports the value of statistic which follows a χ^2 distribution asymptotically with $d.f.$ degrees of freedom under the null hypothesis that the Euler equations (3) hold, *Pvalue* is the one of *Jtest*, each D_i and W_i is the value of D and Wald statistic which tests the hypothesis (4.1) and (4.2) and follows a χ^2 distribution asymptotically with 1 degree of freedom under the null hypothesis that $\phi_i = 0$ and $\phi_i = 1$ holds respectively, and each one of $*$ and $**$ represents the rejection at the upper 5 and 1 % siginificance level respectively.

Appendix B: Data Description

This appendix describes the data in alphabetical order of country names. All data are monthly, and the sample period is 1980.9 through 1988.12. The sources of data are denoted in the parenthis. The following abbreviation will be employed: OECD means OECD Main Economic Indicators.[19] Each annual rate was transformed to three-month rate by the compound interest method, each price level was seasonally adjusted, and the cross exchange rates were computed from the dollar exchange rates.

{*Germany*} P_t^g: Consumer prices, all items, 1985 = 100, not seasonally adjusted (OECD),

M_t^g: Money supply(M1), end of month, seasonally adjusted (OECD),

${}_tR_{t+3}^g$: 3 month time deposit rate (under 1 DM million), percent per annum, end of month (Monthly Report of Deutsche Bundesbank),

$e_t^{us,g}$: spot, end of month (OECD).

{*Japan*} P_t^{jp}: Consumer prices, all items, 1985 = 100, not seasonally adjusted (Monthly Report of Retail Prices, Management and Cordination Agency),

M_t^{jp}: Money supply(M1), end of month, seasonally adjusted (Economic Statistic Monthly, Bank of Japan),

${}_tR_{t+3}^{jp}$: Yields of bond trading with repurchase agreement (3 months), percent per annum, end of month (Newsletter on Bond & Money),

$e_t^{j,us}$: spot, closing, end of month (Ecnomic Statistic Monthly, Bank of Japan). M_t^{jp}, ${}_tR_{t+3}^{jp}$ and P_t^{jp} were taken from Nikkei Needs tape.

{*U.K.*} P_t^{uk}: Consumer prices, all items, 1985 = 100, not seasonally adjusted

[19] The digest book was used.

(OECD),

M_t^{uk}: Money supply(M1), third Wednesday of each month (second in December) prior to October 1986 and end of month thereafter, seasonally adjusted (OECD),

${}_tR_{t+3}^{uk}$: Treasury bill's discount rate(91 days), percent per annum, last issue of month (OECD),

$e_t^{us,uk}$: spot, end of month (OECD).

$\{U.S.A.\}$ P_t^{us}: Consumer prices, all items, 1985 = 100, not seasonally adjusted (OECD),

M_t^{us}: Money supply(M1), daily average, seasonally adjusted (OECD),

${}_tR_{t+3}^{us}$: Treasury bill's discount rate(3 months), percent per annum, last issue of month (Federal Reserve Bulletin).

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