

File ID 61325
Filename Chapter 7 Summary and Conclusions

SOURCE (OR PART OF THE FOLLOWING SOURCE):

Type Dissertation
Title A term structure model of interest rates and forward premia: an alternative monetary approach
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Faculty Faculty of Economics and Business
Year 2002

FULL BIBLIOGRAPHIC DETAILS:

<http://dare.uva.nl/record/104767>

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Chapter 7

Summary and Conclusions

In general, economic theory imply that the domestic price of the foreign currency, given rational expectations, should depreciate when domestic nominal interest rates exceed foreign nominal interest rates. However, the evidence reported in empirical studies is that, in contrast, there is a tendency for high interest rate currencies to appreciate, i.e. future exchange rate changes are negatively correlated with current nominal interest rate differentials. The implication of this anomaly is that the foreign exchange forward rate is not an efficient predictor of the future spot exchange rate, and, therefore, explains the existence of a nonzero forward premium. In this study we examined the foreign exchange forward premium anomaly in the framework of an affine term structure of interest rate model. The motivation for this study is twofold. First, most term structure studies of the forward premium that accounts for the currency puzzle uses a arbitrary framework, namely, the pricing kernel approach. It is not clear whether this no-arbitrage condition is supported by a general equilibrium under plausible assumptions. Second, most equilibrium models of the forward premium fail to account for the anomaly. A striking feature of these models is that they do not allow for an integrated role for money and, therefore, only rely on the correlation between money supply and production to account for the anomaly. As shown by Engel (1992) this correlation is not capable of generating a value large enough to account for the anomaly.

In Chapter 2 we review existing rational expectations models of the currency puzzle, in particular the pricing kernel and general equilibrium models of the forward premium. We distinguish two approaches with respect to the pricing kernel models, namely, the consumption Euler equations and the no-arbitrage approach. The first approach relies on the covariance between the intertemporal marginal rate of substitution and the spot exchange rate to account for the anomaly. Since consumption data do not generate enough variability to account for the large variance of the ex-ante foreign exchange returns, these models must allow for implausible large values for the parameter of relative risk aversion to account for the currency puzzle. We also review no-arbitrage models of the forward premium, that is, models that impose arbitrary restrictions on the pricing kernel. Since in this approach the pricing kernel is not constrained by any particular model, the focus is to find a stochastic process for the kernel that satisfies the Fama conditions. The question in this context is whether an equilibrium model with an intertemporal marginal rate of substitution that is consistent with this stochastic process can be developed. Even in this case, to account for the anomaly may imply implausible parameter values for, among others, the interest rates, exchange rate dynamics, and the "price of risk".

Most general equilibrium models of the currency puzzle are based on a Lucas-Svensson type cash-in-advance framework. In this setup, the economic agents hold cash balances for transaction purposes. The sources of risk in these models is the correlation between the supply of money and the production process. The explanation herefore is that, in equilibrium, the exchange rate is a function only of money, while consumption is a function only of output. For the exchange rate to have non-zero covariance with the marginal rate of substitution of goods, the money supplies must be correlated with the production processes in this framework. The difficulties faced by the Lucas-type models to account for the currency puzzle is that this correlation between money and production cannot generate values large enough to account for the negative covariance between the risk premium and the expected changes in the currency price.

In this context, we can conclude that the large variability of the rate of change of

currency prices and the negative covariance of the risk premium with the expected rate of depreciation imposes severe restrictions on the no-arbitrage and general equilibrium models of the forward risk premium models. As a result, these models have been unable to account for the currency puzzle with plausible parameter restrictions.

In Chapter 3 we present a two-country monetary-production economy. This framework was first developed by CIR (1985a) in a closed economy context, without money. We incorporate money in the CIR-production economy, by allowing for monetary endogeneity and for the risk averse representative agent of each country to hold money for both transaction and portfolio considerations. Five assets are traded in our two-country framework. The representative agents can invest in both production technologies located in each country. In addition they have complete access to the bond markets located in these countries. We allow for the existence of freely trade claims contingent on these assets. In our setup, money holdings as an object of portfolio choice is not distinguishable from nominal bonds, since they have the same risk exposure and covariance with other assets. By including money directly in the utility function of the representative agents, we assume that it provides them with liquidity services. The representative agent of each country maximizes a separable log-utility function, subject to its dynamic budget constraint.

In Chapter 4 we derive the equilibrium conditions in a simplified i.i.d. framework, that is, an economy where both production and money growth are governed by geometric Brownian motions. Despite the fact that in this setup, the equilibrium interest rates and the velocity of monies are constant, it still provides us with a good insight of the equilibrium relations in the economy. The equilibrium in this two-country monetary-production economy endogenously and simultaneously determines the consumption-production plan, demand for both monies, price of both monies, expected rate of inflation, exchange rate, expected rate of depreciation, risk premia, and the market clearing interest rates.

Even in this simplified framework the model displays some important distinguishing features. First, we extend current general equilibrium term structure models by allowing

real and monetary quantities to interact dynamically. In existing literature, separability of the utility function over consumption and money has led to a complete detachment of the real and monetary economy. By introducing monetary endogeneity in a production economy and allowing for money as an object of portfolio choice we avoid this dichotomy. As a result, the equilibrium real and nominal interest rates are determined by both real and nominal variables. Second, our asset pricing model shows that, despite separable preferences, in equilibrium all sources of risk are priced in this economy. Therefore, the risk-averse representative investor receives a compensation in terms of expected excess return for bearing both monetary and production risk. Third, we show that the inflation process is correlated with the instantaneous rate of depreciation of the currency in equilibrium and as such plays a crucial role in restoring equilibrium in this simplified two-country world economy. However, it is inevitable that in this simplified i.i.d. framework that, in equilibrium, the interest rates and volatility of changes in the spot exchange rate are constants. Therefore, despite its simplicity, it is not possible to account for the currency puzzle in this framework.

To account for the forward premium anomaly we allow for stochastic interest rates and volatilities in Chapter 5. This is obtained by assuming a CIR (1985a) production process, which imply that the expected rate of return in production and its volatility are linear in the state variables. We show in this chapter that the stochastic nominal interest rates in this economy have some important properties. First, it allows for stochastic volatilities, with non-zero covariance between the interest rate dynamics and the changes in the nominal interest rate volatility. This is important from an empirical point of view, since it enables the model to capture such features as skewness and leptokurtosis in the interest-rate dynamics. Second, our model permits the stochastic nominal interest rates in each country to be imperfectly correlated with each other. Third, we provide closed-form solution for the price of the nominal discount bond. An important feature of our term structure model is that it allows for rates of different maturities and across countries to be imperfectly correlated.

Our exchange rate model in Chapter 5 shows that the uncovered interest rate parity condition does not hold in this economy, since the expected rate of depreciation of the currency is not only determined by the nominal interest rate differential but also by the stochastic volatilities of both nominal interest dynamics.

In Chapter 5 we also provide closed form expression for the term structure of forward foreign exchange rate and forward premium in equilibrium. Following Fama (1984) we decompose the forward premium into a "risk premium" and an expected depreciation of the currency. We show in this context that the variance of the foreign exchange risk premium is not zero, which implies that indeed the uncovered interest rate parity condition does not hold in this economy. This decomposition allow us to show that our model satisfies the Fama (1984) conditions for accounting for the currency puzzle. Both components of the forward exchange rate premium are time varying, as both the term structure of forward risk premia and expected rate of depreciation are state dependent. In addition, we show that our model is capable of generating negative covariance between the forward risk premium and the expected rate of depreciation and that the variance of risk premia exceeds the variability of the expected rate of depreciation. Since the expected rate of depreciation is determined by the relative production processes in the two countries and the relative rate of return on bonds is determined by the monetary response, the currency puzzle is explained when there is an asymmetric response on the equity/production markets and the bonds/money markets. The latter determine the interest rate, c.q. the bond return, differential while the former determine the equity, c.q. production, return differential.

Our empirical analysis in Chapter 6 focuses on two objectives. First, we validate the equilibrium conditions of our model by testing whether the stochastic processes derived from our model provide an adequate description of the moments of the interest rates and the exchange rate. In addition, we test the cross-sectional restrictions imposed by our model on the term structure of nominal interest rates. Second, we examine the parameter restrictions imposed by the Fama conditions on our model, by calibrating the parameter

values to match both the moments of the interest rates and exchange rate and the Fama (1984) regression slope coefficient. Our sample consist of data for the US and the UK over the period of 1981-2001. We estimate the moments of the variables in question by using the generalized method of moment (GMM) technique of Hansen (1982).

In this context we provide evidence that the stochastic process derived from our theoretical model is supported by the data. This result means that, in equilibrium, the nominal interest rates and the volatility of changes in the nominal interest rates in this two-country world economy are mean reverting in both state variables. We also show that the data supports the equilibrium results of our model for the currency price, namely, that the expected rate of depreciation and the volatility of changes in the exchange rate are a function of the nominal interest rate differential and both volatilities of the nominal interest rate dynamics. Our empirical results indicate that the cross-sectional restrictions of the equilibrium term structure model of nominal interest rates are supported by the data. That is, the interest rate differential have a significant positive but decreasing impact on the yield changes in both countries. Both the US- and UK-yields are sensitive to volatility changes of the short-term interest rate dynamics, mainly at the short end of the yield-curve. These results imply that short-term maturities are more sensitive to short term dynamics, compared to longer-term maturities.

In Chapter 6 we presented the calibrated values for our model parameters. The parameter values have been determined in a way that exactly match the point estimate of the Fama (1984) regression slope parameters for the term structure of foreign exchange return equations and the moments of the underlying variables. This methodology guarantees that our parameter values not only account for the Fama puzzle but also provide an accurate description of the moments of the nominal interest rates, the exchange rate dynamics, and their volatilities. We show in this context that the calibrated parameter values satisfies one of the crucial requirements for a term structure model, namely the Feller (1951) condition. This implies that our model accounts for the Fama condition without allowing for negative nominal interest rates, as in most term structure studies of

the forward premium. The other conditions, such as the variability of the interest rates and exchange rate dynamics and their covariance are satisfied by construction, since we calibrated the parameter values to match these moments.

The calibration results show that the currency puzzle, i.e. the negative covariance between the expected exchange rate returns and the interest rate, c.q. bond return, differential, is due to the asymmetric response on the equity/production markets and bond/money markets. The monetary response to common, say international, shocks in US is stronger than in the UK, which leads to a stronger response in the nominal interest rates, c.q. bond returns, in the US. This means, for example, that a positive shock increases the interest rate differential. In contrast, we can observe, over the sample period (1981-2001) that the rate of return in production in the UK is more sensitive to for instance international shocks than in the US. Since, the expected rate of depreciation is determined by the relative production processes, a positive shock decreases the dollar price of one UK-pound. This shows that the asymmetric affect of e.g. international shocks on the rate of return in production and bonds return explains the negative covariance between the expected rate of depreciation and the interest rate differential.

In conclusion we note that our term structure model of forward premium have some important features. First, most multi-currency term structure models of the forward premium use an arbitrary pricing kernel specification to account for the currency puzzle. It is not clear from these models whether the conditions imposed by the puzzle on these models are supported in a general equilibrium. In contrast to these studies, our general equilibrium two-country term structure model provides an economic explanation for the currency puzzle and the time-varying risk premium.

Second, in accounting for the anomaly, previous general equilibrium multi-currency term structure models place implausible requirements on the market prices of risk and the parameter values. Our model provides a richer and more plausible explanation of the puzzle because it allows interactions between monetary and real quantities. Because of monetary endogeneity, the forward risk premium and the expected depreciation of

the exchange rate depend on the money supply process and the real rate of return of production. As a result, discrepancies in the domestic and foreign monetary responses can also account for the forward premium puzzle.

Third, other potential sources for the anomaly on the foreign currency markets are asymmetries on the equity and bond markets in our economies. Risk and return differentials on these securities markets can account for the anomaly. In contrast to existing term structure models, this explanation does not require extreme parameter values for the factor volatilities and counterfactual risk premiums. This key result is due to the stochastic investment opportunity sets and the monetary endogeneity. In this context it should be noted that our model is also capable of explaining the equity premium puzzle based on this asymmetries [see Mehra and Prescott (1985) and Fase and Poll (1996)].