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**Article**

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NBER Reporter Online

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National Bureau of Economic Research (NBER), Cambridge, Mass.

*Suggested Citation:* Engel, Charles (2006) : Exchange-rate models, NBER Reporter Online, National Bureau of Economic Research (NBER), Cambridge, MA, Iss. Fall 2006, pp. 17-20

This Version is available at:

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Managerial and Decision Economics.  
<sup>5</sup> For effects of regulation on productivity, see P.M. Danzon and A. Percy, "The Effect of Price Regulation on Productivity in the Pharmaceutical Industry," in *Studies in Income and Productivity*, A. Heston and R. Lipsey, eds. Chicago: U.Chicago Press, 2000.

<sup>6</sup> P. M. Danzon and J. Ketcham, "Reference Pricing of Pharmaceuticals for Medicare: Evidence from Germany, the Netherlands and New Zealand," in *Frontiers in Health Policy Research*, Vol. 7, D. M. Cutler and A. M. Garber, eds. MIT Press: Cambridge, 2004.

<sup>7</sup> P. M. Danzon, Y. R. Wang, et al. (2005), "The impact of price regulation on

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<sup>9</sup> P. M. Danzon and M. F. Furukawa, (2003), "Prices and availability of pharmaceuticals: Evidence from nine countries," *Health Affairs* 22(6): W521–W536.

<sup>10</sup> P. M. Danzon and M. F. Furukawa, (forthcoming 2006), "Prices and availability of biopharmaceuticals: An international comparison," *Health Affairs*.

## Exchange-Rate Models

Charles Engel\*

Recent research that my co-authors and I have undertaken, as well as related research by other NBER researchers, suggests that theoretical models of foreign exchange rates are "not as bad as you think." Since the 1970s, models have emphasized the role of exchange rates as asset prices. The new work, looking at present-value models of exchange rates, highlights the role of expectations in determining exchange rate movements. In this article, I briefly summarize some of the work that I have been involved with, along with a few related papers by other researchers. I also report on some research that has drawn the implications of this new work on exchange rates for open-economy macroeconomic policy.

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### Should Exchange Rate Models Out-predict the Random Walk Model?

For many years, the standard criterion for judging exchange rate models has been, do they beat the random-walk model for forecasting changes in exchange rates? This criterion was popularized by the seminal work of Meese and Rogoff.<sup>1</sup> They found that the empirical exchange rate models of the 1970s that seemed to fit very well in-sample tended to have a very poor out-of-sample fit. The mean-squared error of the model's prediction of the exchange rate (using realized values of the explanatory variables) tended to be lower than the mean-squared error of the naïve model that predicts no change in the exchange rate. While Meese and Rogoff's exercise was not strictly speaking "forecasting" (because it used realized explanatory variables to "predict" the exchange rate),

subsequent work has evaluated exchange rate models by the criterion of whether they produce forecasts with a lower mean-squared error than the simple random walk forecast of no change. Mark's (1995) paper was important in reviving interest in empirical exchange rate models.<sup>2</sup> He found that the models were helpful in predicting exchange rates at long horizons. Subsequent work has cast doubt on whether exchange rates can be forecast at long horizons, so there is a weak consensus that the models are not very helpful in forecasting. (It is worth noting that there is a contingent that believes that non-linear models have forecasting power. When exchange rates are far out of line with the fundamentals, the models are useful in predicting that the exchange rate will return to its fundamental level.)

West and I<sup>3</sup> question the standard criterion for judging exchange rate models. Many exchange rate models can be writ-

ten so that they explain the exchange rate as a weighted sum of current “fundamentals” (such as money supplies, prices, output levels) and the expected future value of the exchange rate. The models actually put relatively little weight on the current fundamentals and much more weight on expectations. The realization of the current fundamental may affect the exchange rate indirectly by influencing the expected future exchange rate. But markets use many sources of information to form expectations of the future exchange rate, not just the realizations of the current fundamentals. So, the models imply that innovations in the current fundamental may not have a large effect on the exchange rate.

This type of model can be solved forward to express the exchange rate as the expected present discounted value of current and future fundamentals. West and I demonstrate the following result for this class of models: if the fundamentals are integrated of order 1 (that is, their first difference is stationary), and the discount factor is close to one, then the exchange rate will approximately follow a random walk. One important implication of this result is that the standard criterion used in evaluating exchange rate models -- can the models out-forecast a random walk? -- is not useful here. The Engel-West result shows that the models actually imply that the exchange rate will approximately follow a random walk. Evidence that they do not perform better than a random walk in forecasting exchange rates cannot be taken as evidence against the models. In practice for typical exchange rate models, West and I show that — given the value of discount factors measured in previous studies and the empirical properties of the fundamentals — the models indeed imply that exchange rates are nearly a random walk.

## Other Means of Evaluating Exchange Rate Models

We argue that the Campbell-Shiller<sup>4</sup> technique for evaluating present-value models should not be applied to exchange rate models because all researchers acknowledge that some of the important fundamentals — errors in money demand, foreign-exchange risk premiums,

the equilibrium real exchange rate — are not observed by the econometrician. The Campbell-Shiller technique implicitly requires that we know and observe all of the relevant fundamentals that determine the asset price.

But how closely linked are the “observed” fundamentals to exchange rates? West and I<sup>5</sup> note that, since the exchange rate is supposed to be the expected present value of current and future fundamentals, perhaps the exchange rate is useful in forecasting some of the observed fundamentals. In that paper we indeed find (weak) evidence to confirm the hypothesis. Note that since the exchange rate also moves with news about future “unobserved” fundamentals, we should not expect it to be an excellent forecaster of the observed fundamentals alone.

## How Much of the Volatility of Exchange Rates is Accounted for by the “Observed Fundamentals”?

A separate criticism of the present value models of exchange rates is that the volatility of the present value is smaller in practice than the volatility of the exchange rate. That is actually the opposite of the way it should be. Calculating the present value requires making a forecast of future fundamentals. Researchers do not have all the information that the markets use in constructing forecasts, so their forecasts should have higher variance than the markets’.

An implication of the Campbell-Shiller technique is that if researchers used the asset price to forecast the fundamentals, they would have all the information that markets use, because that information is reflected in the asset price. But the exchange rate reflects information only about the true fundamental, not the component of the fundamental observed by the econometrician. Still, West and I<sup>6</sup> demonstrate that, again when the discount factor is near one, the variance in innovations of the discounted sum of current and expected future fundamentals calculated by the researcher with his inferior information set is approximately

equal to the variance in innovations of the present value when forecasts are based on the market’s information.

With that result in hand, we are able to ask how the conditional variance of the discounted present value of expected observed fundamentals compares with the conditional variance of the exchange rate. The answer is that the observed fundamentals for a few commonly used exchange rate models account for, on average, about 40 percent of exchange rate volatility. While this still means that either left-out fundamentals account for much of the volatility, or that there is excess volatility, it is encouraging relative to previous work. It no longer seems so hopeless that an improved exchange rate model can account for exchange rate volatility.

Indeed, perhaps such a model can be developed out of the new line of macroeconomic research that has emphasized that monetary policy is set as a Taylor rule: interest rates are set to respond to inflation, the output gap, and perhaps other economic variables. West and I<sup>7</sup> provide some favorable evidence for such models. We<sup>8</sup> show that the Taylor-rule model, when expressed as a present value relationship, has a modest positive correlation with the actual real dollar/DM rate over the 1979–98 period. An interesting implication of the model is that an increase in expected future inflation in a country actually causes the currency to appreciate. The reason for this is that under the Taylor rule, the policymaker raises interest rates more than the increase in expected inflation. This aspect of the model plays an important role in tracking the actual dollar/DM rate.

Mark’s paper is closely related.<sup>9</sup> There are a few differences, two of which merit mention here. The first is a minor point conceptually, but seems to have important empirical implications. In modeling the Taylor rule, Mark allows for sluggish adjustment in the nominal interest rate, which is a feature of actual interest rate behavior that is well known in the literature. This modification appears to be partly responsible for the fact that Mark’s empirical model produces an exchange rate that is much more volatile than

Engel and West's—indeed, the model's exchange rate is slightly more volatile than the actual exchange rate. The second point is important conceptually, but seems to have modest empirical implications. Mark allows for the possibility that agents do not know central bank policy and learn about it over time. While in Mark's formulation, this modification does not play a large role in explaining movements in exchange rates, I believe it is an important step in trying to get a handle on the formation of expectations.

Another important step in this direction is the contribution of Bacchetta and van Wincoop.<sup>10</sup> They examine exchange rate determination in a simple model in which agents have different information about future economic fundamentals. Perhaps it is most plausible to think of this as different forecasters using different techniques to analyze the future evolution of the economy. They emphasize how agents must try to infer the information that other agents have from the movements in exchange rates. Agents must forecast the forecasts of others—that is, they must form “higher-order beliefs”. Kasa, Walker, and Whiteman<sup>11</sup> have drawn an interesting link between this line of research and my paper with West on volatility. They show that introducing higher-order beliefs into a standard exchange rate model works like an “unobserved fundamental”.

Since expectations are the prime mover of exchange rates and expectations change only when there is news, we can ask whether exchange rates respond to news in the way the models predict. That is exactly the exercise undertaken by Clarida and Waldman.<sup>12</sup> As noted above, Taylor-rule models imply that a country's currency will appreciate when there is news of higher inflation. Clarida and Waldman examine announcements of inflation rates, compared to survey expectations of what the announced inflation rate will be. They find that when the announcement is that inflation is unexpectedly high, the currency tends to appreciate. That relationship is strong in countries that explicitly target inflation and is weaker or non-existent in countries that do not target inflation.

## Conclusions and Implications

It is difficult to evaluate exchange rate models. Models of asset prices in general are difficult to test because asset price changes are driven by changes in expectations of future fundamentals. It is hard for the researcher to measure expectations. The problem is compounded in the case of exchange rates because we know that there are some components of the fundamentals that we cannot directly observe. Still, the recent research first refutes the notion that the failure of the models to predict exchange rate changes is strong evidence against the models. And, there is some favorable evidence: exchange rates contain news about future fundamentals; they are not so excessively volatile as the literature once accepted; Taylor-rule models show some promise; and, exchange rates respond to news in the way the models predict.

In closing I turn to my paper with Devereux,<sup>13</sup> which explores the implications of the fact that exchange rates respond primarily to news about future fundamentals. An overly brief synopsis of the main lesson from the new Keynesian economics is that monetary policy should aim—to the extent it can—to eliminate the distortions introduced by sticky nominal prices. Ideally, monetary policy should try to reproduce the outcome that would be achieved if nominal prices were flexible. We show that, in an open economy there is a problem when we mix the fact that the nominal exchange rate of any country pair responds to news about the future with the fact that there are nominal goods prices that are set in the currency of each country. Then, relative prices—the prices of goods set in one currency relative to those set in another currency—will change when the nominal exchange rate changes. The problem is that those relative prices are changing when there is news about future fundamentals (monetary and real) that drive the nominal exchange rate. If goods prices were flexible, then relative goods prices would not be influenced by news about the future that is driving the nominal exchange rate. This is a distortion in relative prices caused by nominal price stickiness. Our paper argues that,

since most of the variation in exchange rates comes from news about these future fundamentals, most exchange rate variation generates inefficient relative price movements. We argue that there is a case for monetary policy to target unexpected changes in nominal exchange rates in addition to targeting inflation.

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<sup>2</sup> N. C. Mark, 1995, “Exchange Rates and Fundamentals: Evidence on Long-Horizon Predictability,” *American Economic Review* 85 (March), pp. 201–18.

<sup>3</sup> C. Engel and K. D. West, “Exchange Rates and Fundamentals,” NBER Working Paper No. 10723, September 2004, published in *Journal of Political Economy* 113 (June 2005), pp. 485–517.

<sup>4</sup> J. Y. Campbell and R. J. Shiller, “Cointegration and Tests of Present Value Models,” NBER Working Paper No. 1885, June 1988, published in *Journal of Political Economy* 95 (October 1987), pp. 1062–88.

<sup>5</sup> C. Engel and K. D. West, “Exchange Rates and Fundamentals,” *op. cit.*

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<sup>8</sup> C. Engel and K. D. West, “Taylor Rules...” *op. cit.*

<sup>9</sup> N. C. Mark, “Changing Monetary Policy Rules, Learning, and Real Exchange Rate Dynamics,” NBER Working Paper No. 11061, January 2005.

<sup>10</sup> P. Bacchetta and E. van Wincoop, “Can Information Heterogeneity Explain the



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<sup>12</sup> R. Clarida and D. Waldman, “Is Bad News about Inflation Good News for the Exchange Rate?” in J. Y. Campbell, ed., *Asset Prices and Monetary Policy,*

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<sup>13</sup> M. B. Devereux and C. Engel, “Expectations and Exchange Rate Policy,” NBER Working Paper No. 12213, May 2006.

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Torben G. Andersen is a Research Associate in the NBER’s Program on Asset Pricing. He is also the Nathan S. and Mary P. Sharp Distinguished Professor of Finance at Northwestern University’s Kellogg School of Management, and is the chair of the International Business and Markets Program there.

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Andersen is married with three children and lives in Evanston, Illinois. In his free time he enjoys traveling, music, and sports.



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## NBER Profile: *Andrew B. Bernard*

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Andrew Bernard is an NBER Research Associate in the Program on International Trade and Investment and the Jack Byrne Professor of International Economics at the Tuck School of Business at Dartmouth. Originally from New York City, he received his A.B. from Harvard University in 1985 and his Ph.D. in economics from Stanford University in 1991.

Bernard began his academic career in the economics department at MIT in 1991 before joining the Yale School of Management in 1997. In 1999, he left Yale for Tuck where he was promoted to full professor in 2003. At Tuck, Bernard also serves as Senior Associate Director of the Center for International Business.

Bernard’s research examines the role of

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Bernard lives in Hanover, New Hampshire with his wife, Corinne Fortune, and their two sons, Spencer and Henry. He enjoys seeing pileated woodpeckers outside his office window and quadrennially prognosticating about the summer Olympics using nothing more than economics.