Journal of International Economics xxx (2013) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Journal of International Economics

journal homepage: www.elsevier.com/locate/jie

Robustness and exchange rate volatility☆

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ARTICLE INFO

Article history:
Received 16 February 2012
Received in revised form 21 May 2013
Accepted 23 May 2013
Available online xxxx

JEL classification:
F31
D81

Keywords:
Volatility
Robustness
Exchange rates

ABSTRACT

This paper studies exchange rate volatility within the context of the monetary model of exchange rates. We assume that agents regard this model as merely a benchmark, or reference model, and attempt to construct forecasts that are robust to model misspecification. We show that revisions of robust forecasts are more volatile than revisions of nonrobust forecasts, and that empirically plausible concerns for model misspecification can explain observed exchange rate volatility. We also briefly discuss the implications of robust forecasts for a number of other exchange rate puzzles.

1. Introduction

Exchange rate volatility remains a mystery. Over the years, many explanations have been offered — bubbles, sunspots, 'unobserved fundamentals', noise traders, etcetera. Our paper offers a new explanation. Our explanation is based on a disciplined retreat from the Rational Expectations Hypothesis. The Rational Expectations Hypothesis involves two assumptions: (1) agents know the correct model of the economy (at least up to a small handful of unknown parameters, which can be learned about using Bayes' rule), and (2) given their knowledge of the model, agents make statistically optimal forecasts. In this paper, we try to retain the idea that agents process information efficiently, while at the same time relaxing what we view as the more controversial assumption, namely, that agents know the correct model up to a finite dimensional parameterization.

Of course, if agents don't know the model, and do not have conventional finite-dimensional priors about it, the obvious question becomes — how are they supposed to forecast the future? Our answer is to suppose that agents possess a simple benchmark model of the economy, containing a few key macroeconomic variables. We further suppose that agents are aware of their own ignorance, and respond to it strategically by constructing forecasts from the benchmark model that are robust to a wide spectrum of potential misspecifications. We show that revisions of robust forecasts are quite sensitive to new information, and in the case of exchange rates, can easily account for observed exchange rate volatility.

Our paper is closely related to prior work by Hansen and Sargent (2008), Kasa (2001), and Lewis and Whiteman (2008). Hansen and Sargent have pioneered the application of robust control methods in economics. This literature formalizes the idea of a robust policy or forecast by viewing agents as solving dynamic zero sum games, in which a so-called 'evil agent' attempts to subvert the control or forecasting efforts of the decision maker. Hansen and Sargent show that concerns for robustness and model misspecification shed light on a wide variety of asset market phenomena, although they do not focus on exchange rate volatility. Kasa (2001) used frequency domain methods to derive a robust version of the well-known Hansen and Sargent (1980) prediction formula. This formula is a key input to all present value asset pricing models. Lewis and Whiteman (2008) use this formula to study stock market volatility. They show that concerns for model misspecification can explain observed violations of Shiller's variance bound. They also apply a version of Hansen and Sargent's detection error probabilities to gauge the empirical plausibility of the agent's fear of model misspecification. Since robust forecasts are the outcome of a minmax control problem, one needs to make sure that agents are not being excessively pessimistic, by hedging against models that could have been easily rejected on the basis of observed historical time series. Lewis and Whiteman's results suggest that explaining stock market volatility solely on the basis of a concern for robustness requires an excessive degree of pessimism

☆ We would like to thank two anonymous referees for helpful comments. We also received useful suggestions from seminar participants at HKU and HKUST.

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0022-1996/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jinteco.2013.05.003

on the part of market participants. Interestingly, when we modify their detection error calculations slightly, we find that robust forecasts *can* explain observed exchange rate volatility.[1]

Since there are already many explanations of exchange rate volatility, a fair question at this point is — why do we need another one? We claim that our approach enjoys several advantages compared to existing explanations. Although bubbles and sunspots can obviously generate a lot of volatility, these models require an extreme degree of expectation coordination. So far, no one has provided a convincing story for how bubbles or sunspots emerge in the first place. Our approach requires a more modest degree of coordination. Agents must merely agree on a simple benchmark model, and be aware of the fact that this model may be misspecified.[2] It is also clear that noise traders can generate a lot of volatility. However, as with bubbles and sunspots, there is not yet a convincing story for where these noise traders come from, and why they aren't driven from the market. An attractive feature of our approach is that, if anything, agents in our model are *smarter* than usual, since they are aware of their own lack of knowledge about the economy.[3]

Our approach is perhaps most closely related to the 'unobserved fundamentals' arguments in West (1987), Engel and West (2004), and Engel et al. (2007). These papers all point out that volatility tests aren't very informative unless one is confident that the full array of macroeconomic fundamentals are captured by a model.[4] As a result, they argue that rather than test whether markets are 'excessively volatile', it is more informative to simply compute the fraction of observed exchange rate volatility that *can* be accounted for by innovations in observed fundamentals. Our perspective is similar, yet subtlely different. In West, Engel–West, and Engel–Mark–West, fundamentals are only unobserved by the outside econometrician. Agents within the (Rational Expectations) model are presumed to observe them. In contrast, in our model it is the agents themselves who suspect that there might be missing fundamentals, in the form of unobserved shocks that are correlated both over time and with the observed fundamentals. In fact, however, their benchmark model could be perfectly well specified. (In the words of Hansen and Sargent, their doubts are only 'in their heads'). It is simply the prudent belief that they *could be* wrong that makes agents aggressively revise forecasts in response to new information.

In contrast to 'unobserved fundamentals' explanations, which are obviously untestable, there is a sense in which our model *is* testable. Since specification doubts are only 'in their heads', we can ask whether an empirically plausible degree of doubt can rationalize observed exchange rate volatility. That is, we only permit agents to worry about alternative models that could have plausibly generated the observed time series of exchange rates and fundamentals, where plausible is defined as an acceptable detection error probability, in close analogy to a significance level in a traditional hypothesis test. We find that given a sample size in the range of 100–150 quarterly observations, detection error probabilities in the range of 10–20% can explain observed exchange rate volatility.

The remainder of the paper is organized as follows. Section 2 briefly outlines the monetary model of exchange rates. We assume that agents regard this model as merely a benchmark, and so construct forecasts that are robust to a diffuse array of unstructured alternatives. Section 3 briefly summarizes the data. We examine quarterly data from 1973:1–2011:3 on six US dollar bilateral exchange rates: the Australian dollar, the Canadian dollar, the Danish kroner, the Japanese yen, the Swiss franc, and the British pound. Section 4 contains the results of a battery of traditional excess volatility tests: Shiller's original bound applied to linearly detrended data, the bounds of West (1988) and Campbell and Shiller (1987), which are robust to inside information and unit roots, and finally, a couple of more recent tests proposed by Engel and West (2004) and Engel (2005). Although the results differ somewhat by test and currency, a fairly consistent picture of excess volatility emerges. Section 5 contains the results of our robust volatility bounds. We first apply Kasa's (2001) robust Hansen–Sargent prediction formula, based on a so-called H^{∞} approach to robustness, and show that in this case the model actually predicts that exchange rates should be far *more* volatile than the observed exchange rate volatility. We then follow Lewis and Whiteman (2008) and solve a frequency domain version of Hansen and Sargent's evil agent game, which allows us to calibrate the degree of robustness to detection error probabilities. This is accomplished by assigning a penalty parameter to the evil agent's actions. We find that observed exchange rate volatility can be explained if agents are hedging against models that have a 10–20% chance of being the true data-generating process. Section 6 relates robustness to other puzzles in the foreign exchange market. In particular, we show that robust forecasts can explain the forward premium puzzle. In fact, explaining the forward premium puzzle is *easier* than explaining the volatility puzzle, since the associated detection error probabilities are larger. Section 7 contains a few concluding remarks.

2. The monetary model of exchange rates

The monetary model has been a workhorse model in open-economy macroeconomics. It is a linear, partial equilibrium model, which combines Purchasing Power Parity (PPP), Uncovered Interest Parity (UIP), and reduced-form money demand equations to derive a simple first-order expectational difference equation for the exchange rate. It presumes monetary policy and other fundamentals are exogenous. Of course, there is evidence against each of these underlying ingredients. An outside econometrician would have reasons to doubt the specification of the model. Unlike previous variance bounds tests using this model, we assume that the agents within the model share these specification doubts.

Since the model is well known, we shall not go into details. (See, e.g., Mark, 2001 for a detailed exposition). Combining PPP, UIP, and identical log-linear money demands yields the following exchange rate equation:

$$s_t = (1-\beta)f_t + \beta E_t s_{t+1} \tag{2.1}$$

where s_t is the log of the spot exchange rate, defined as the price of foreign currency. The variable f_t represents the underlying macroeconomic fundamentals. In the monetary model, it is just

$$f_t = (m_t - m_t^*) - \lambda(y_t - y_t^*)$$

where m_t is the log of the money supply, y_t is the log of output, and asterisks denote foreign variables. In what follows, we assume $\lambda = 1$, where λ is the income elasticity of money demand. The key feature of

[1] This is not the first paper to apply robust control methods to the foreign exchange market. Li and Tornell (2008) show that a particular type of structured uncertainty can explain the forward premium puzzle. However, they do not calculate detection error probabilities. Colacito and Croce (2011) develop a dynamic general equilibrium model with time-varying risk premia, and study its implications for exchange rate volatility. They adopt a 'dual' perspective, by focusing on a risk-sensitivity interpretation of robust control. However, they do not focus on Shiller bounds or detection error probabilities, as we do here.

[2] On bubbles, see inter alia Meese (1986) and Evans (1986). On sunspots, see Manuelli and Peck (1990) and King et al. (1992). It should be noted that there *are* ways to motivate the emergence of sunspots via an adaptive learning process (Woodford, 1990), but then this just changes the question as to how agents coordinated on a very particular learning rule.

[3] On the role of noise traders in fx markets, see Jeanne and Rose (2002). A more subtle way noise traders can generate volatility is to prevent prices from revealing other traders' private information. This can produce a hierarchy of higher order beliefs about other traders' expectations. Kasa et al. (2010) show that these higher order belief dynamics can explain observed violations of Shiller bounds in the US stock market.

[4] Remember, there is an important difference between unobserved fundamentals and unobserved information about observed fundamentals. The latter can easily be accommodated using the methods of Campbell and Shiller (1987) or West (1988).

Please cite this article as: Djeutem, E., Kasa, K., Robustness and exchange rate volatility, Journal of International Economics (2013), http://dx.doi.org/10.1016/j.jinteco.2013.05.003