

# Delayed Overshooting: Is It an '80s Puzzle?

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We reinvestigate the delayed overshooting puzzle. Using a method of sign restrictions, we find that delayed overshooting is primarily a phenomenon of the 1980s when the Fed was under the chairmanship of Paul Volcker. Related findings are as follows: (1) Uncovered interest parity fails to hold during the Volcker era and tends to hold during the post-Volcker era; (2) US monetary policy shocks have substantial impacts on exchange rate variations but misleadingly appear to have small impacts when monetary policy regimes are pooled. In brief, we confirm Dornbusch's overshooting hypothesis.

## I. Introduction

The delayed overshooting puzzle refers to an empirical tendency by which a domestic monetary contraction induces a protracted phase of apprecia-

We are very grateful to the editor (Harald Uhlig) and four anonymous referees for their comments, which have substantially improved our paper. We thank seminar participants at Sogang University and the Macroeconomic Division of the Korean Econometric Society. Support from the Ministerio Economía y Competitividad (Spain), grants ECO2010-19357, SEJ2007-62908, ECO2012-31748, ECO2014-57007p, and MDM 2014-0431, Comunidad de

Electronically published August 22, 2017

[*Journal of Political Economy*, 2017, vol. 125, no. 5]

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tion of the domestic currency prior to a gradual depreciation.<sup>1</sup> Reinvestigating the puzzle, we examine the conditional response of exchange rates for 14 US trading partners over the 1976–2007 period. We identify US monetary policy shocks by using the method of sign restrictions developed by Uhlig (2005) and Scholl and Uhlig (2008).<sup>2</sup>

In an investigation of the puzzling behavior of exchange rates conditional on monetary policy shocks, a natural starting point is to consider recognizable shifts in the monetary policy regime. Our approach follows the simple procedure of comparing the behavior of exchange rates over three different periods: the entire sample period, the Volcker era, and the post-Volcker era. Arguably, the Volcker monetary policy regime is “the most widely discussed and visible macroeconomic event of the last 50 years of U.S. history” (Goodfriend and King 2005, 981).<sup>3</sup> Our division of the sample period based on historical episodes also coincides with the dates of structural breaks reported in the literature. For example, Bernanke and Mihov (1998) provide evidence of structural changes in 1980 and 1988 (or 1989) using Andrews’s (1993) test for structural breaks with unknown dates. Concerning possible changes in the US Fed’s reaction function proxied by the Taylor rule, Judd and Rudebusch (1998) also report statistical results that strongly reject the continuity hypotheses between the Burns-Miller and Volcker terms and between the Volcker and Greenspan terms.<sup>4</sup>

Our reinvestigation finds, first, that the delayed overshooting in response to US monetary policy shocks appears to prevail in the entire sample period and, second, that one particular subsample period, the Volcker era, is primarily responsible for the first result. Exchange rates overshoot immediately on impact of US monetary policy shocks during the post-

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Madrid, and MadEco-CM (S2015/HUM-3444) is gratefully acknowledged. Data are provided as supplementary material online.

<sup>1</sup> Eichenbaum and Evans (1995) and Grilli and Roubini (1996) document significant delayed overshooting (up to 3 years) based on a recursive identification scheme. This puzzling behavior is further confirmed by several subsequent studies that employ different identification schemes and/or different vector autoregressive (VAR) specifications. See, e.g., Clarida and Gali (1994), Kim (2005), and Scholl and Uhlig (2008).

<sup>2</sup> We thank Almut Scholl for kindly providing us with relevant Matlab programs.

<sup>3</sup> One of the most notable features of the Volcker monetary policy regime is that the contemporary observers in the late 1970s and early 1980s considered the Volcker Fed’s disinflation plan to be incredible and expected a policy U-turn. In Sec. VI, we will examine the key features of the Volcker Fed in detail.

<sup>4</sup> Besides, a number of studies primarily focus on possible structural breaks after Volcker entered office and thus examine the “Volcker-Greenspan” years as one homogeneous monetary regime. See, e.g., Taylor (1999), Clarida, Gali, and Gertler (2000), and Gali, Lopez-Salido, and Valles (2003). However, other works focus on the post-1984 period during which the US economy experienced both stabilized inflation and output changes (see, e.g., Stock and Watson 2002; Gali and Gambetti 2009). These studies adopt such a focus primarily because they are motivated by the Great Moderation and its key features, such as the primary policy instrument, policy mode (accommodative or preemptive), and the economy’s responses to shocks, etc.

Volcker era.<sup>5</sup> In sum, the delayed overshooting during the Volcker era is severe enough to contaminate the entire sample period, thereby misleading previous empirical studies to prematurely conclude the failure of Dornbusch's (1976) overshooting hypothesis.

One explanation for the results can be found in the close connection between the overshooting hypothesis and its key assumption, uncovered interest parity (UIP). Similarly to our results regarding the behavior of exchange rates, UIP, both conditional and unconditional, fails during the Volcker era but tends to hold during the post-Volcker era. The conditional excess returns on foreign currency following US monetary shocks are positive in the Volcker era and close to zero in the post-Volcker era. While this result concerns UIP conditional on monetary policy shocks, UIP unconditional on all possible shocks also fails during the Volcker era: using serial dependence tests, we find that highly predictable foreign excess returns are observed only in the Volcker era. This result regarding the failure and prevalence of UIP is associated with the result regarding delayed overshooting and immediate overshooting. Our study confirms a close link between the overshooting hypothesis and the UIP assumption.

The monetary policy regime may underlie exchange rate movements. We address the issue in two ways within our empirical framework. First, we decompose the forecast error variance of the exchange rate movements within a Bayesian VAR framework. In contrast to previous studies, the maximal share of exchange rate fluctuations attributable to US monetary shocks is quite large for all subsample periods. More importantly, the share follows the same pattern as the impulse response of exchange rates: on average, US monetary policy shocks account for approximately 18 percent of the aggregate exchange rate (named AGGX) fluctuations over the 20–36-month horizon at the median estimate in the Volcker era and for 43 percent of such fluctuations over the 0–4-month horizon in the post-Volcker era, respectively. However, if we pool the subsample periods without considering the history of US monetary policy regimes, the monetary policy shocks seemingly account for little of the exchange rate fluctuations (at most 10 percent over a 5-year horizon). This result occurs primarily because, owing to the large dispersion in the timing of maximal accountability across the subsample periods, the impacts of US monetary shocks on

<sup>5</sup> Most existing empirical studies reporting a tendency of immediate overshooting employ identification schemes that relax the dubious assumptions required by the recursive identification method. See, e.g., Cushman and Zha (1997), Kim and Roubini (2000), and Bjornland (2009) for conditional responses to non-US monetary shocks and Faust and Rogers (2003) for those to US monetary shocks. In recent studies, Binder, Chen, and Zhang (2010) and Forni and Gambetti (2010) claim that the puzzle is eliminated once certain issues regarding the identification of monetary shocks, such as the reactions of other central banks to US monetary shocks or the sizes of the information sets held by central banks and private sectors, are properly accounted for. In contrast, we focus on recognizing shifts in the US monetary policy regime.

exchange rate fluctuations cancel one another out in the entire sample period. By implication, the failure to distinguish “the most widely discussed and visible” US monetary policy regime leads to the premature conclusion that Dornbusch’s overshooting hypothesis fails to hold and that monetary shocks have little impact on exchange rates.

Second, provided that the processes that generate all other shocks have not experienced a structural break from one monetary regime to another, the unconditional movements of exchange rates in response to all possible shocks should also exhibit distinguishable movements between different monetary regimes. We test this prediction by using the variance ratio test for the serial dependence of exchange returns over long horizons. We find distinctly contrasting patterns of serial dependence in exchange rate movements between the Volcker era and the post-Volcker era: only during the Volcker era, changes in exchange rates exhibit a hump-shaped pattern of serial dependence over long horizons. This result regarding the unconditional movements is fully consistent with an implication of delayed overshooting. In brief, the monetary policy regime underlies the movements of exchange rates.

The rest of this paper is organized as follows: Section II describes the data and identification methods. Section III documents the conditional behavior of exchange rates following US monetary policy shocks and establishes that delayed overshooting is primarily a phenomenon of the Volcker era. Section IV reports the variability of exchange rates attributable to US monetary policy shocks and the unconditional behavior of exchange rates. Section V studies conditional and unconditional UIP. Section VI proposes an explanation for the extraordinary behavior of exchange rates during the Volcker era. Section VII presents conclusions. Considering all of the relationships between conditional exchange rate movements and conditional UIP (Secs. III.A and V.A), between conditional and unconditional exchange rate movements (Secs. III.A and IV.B), and between conditional and unconditional UIP (Secs. V.A and V.B), we conclude that exchange rate movements and UIP are as cohesively related in data as they are in theory.

## II. Empirical Methods

### A. Data

Our data set covers 14 US trading partners: Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), France (FR), Germany (GE), Italy (IT), Japan (JP), the Netherlands (NL), Norway (NO), Spain (ES), Sweden (SE), Switzerland (CH), and the United Kingdom (UK). It contains monthly data from 1976:1 to 2007:7. We select the beginning date to make it economically sensible in line with Hansen and Hodrick (1983) and the end

date to separate from the recent financial crisis.<sup>6</sup> For the member countries of the European Monetary Union (EMU), the sample period ends in 1998. However, the sample period for GE is extended to 2007 by replacing the US-GE exchange rate with the US-Euro rate after 1998 based on the fixed GE-Euro rate. See the Appendix for the source of the data.

Our discussion focuses on the aggregates of the 14 US trading partners. We construct aggregates by using two aggregation methods, named “AGG98” and “AGG.” The AGG98 method uses all 14 trading partners prior to 1999 in consideration of the lifetime of EMU member currencies, where each country is weighted by its GDP relative to the total GDP for all 14 countries at purchasing power parity values. The AGG method extends the series until 2007 and considers the non-EMU countries plus GE, while treating GE as a representative of the EMU countries over the entire sample period (1976–2007). For example, the aggregate exchange rate corresponding to AGG98 is calculated by a GDP-weighted average of the 14 bilateral exchange rates. The aggregate exchange rate corresponding to AGG is constructed with the weight for GE calculated by the total EMU GDP relative to the total GDP for all 14 countries. The Appendix provides detailed information on the aggregation procedures.

Each series is divided into the two subsamples: the Volcker and post-Volcker eras. The Volcker era spans from 1979:8 to 1987:12 for both the aggregates and the individual countries. The post-Volcker era spans from 1988:1 to 1998:12 for AGG98 and from 1988:1 to 2007:7 for AGG.

### *B. Identification of US Monetary Policy Shocks*

The main feature of our methodology is that we bring US monetary policy regimes to the fore of our empirical reinvestigation of exchange rate behavior in response to US monetary policy shocks. To facilitate a comparison between our results and implications and those of previous studies, we control for all other methodological aspects and use similar empirical methods. With respect to model specification, we follow Eichenbaum and Evans (1995). Our VAR specification includes seven variables: US and for-

<sup>6</sup> According to Hansen and Hodrick (1983), it is not until January 1976 that the major countries (France, Germany, Italy, Japan, United Kingdom, and United States) reached a consensus and the Interim Committee of the International Monetary Fund ratified it regarding the transition to our modern flexible exchange rate regime. Thus until then “there was considerable uncertainty regarding the future of the international monetary system” and “the forecasting properties of forward exchange rates as well as the monetary and exchange market intervention policy rules of the countries may have been different before and after the agreement” (Hansen and Hodrick 1983, 122). Besides, we also separate the financial crisis period from the main part of our analysis since borrowings from the Fed’s liquidity facilities were larger than total reserves (thereby leading to negative nonborrowed reserves) over much of 2008 to meet the Federal Open Market Committee objective for the federal funds rate.

eign industrial production  $y$  and  $y^*$ , US and foreign 3-month interest rates  $i$  and  $i^*$ , the ratio of US nonborrowed to total reserves  $nbrx$ , US consumer price index (CPI)  $p$ , and the real exchange rate  $s + p^* - p$ , where  $s$  is the nominal exchange rate defined as the price of the foreign currency in terms of the US dollar and  $p^*$  is the foreign CPI. Throughout the paper, we consider the United States to be the home country. When examining the behavior of nominal exchange rates, the VAR specification simply replaces the real exchange rate with the nominal exchange rate. All variables are in logs, except for the interest rates.

With respect to identification, we use Scholl and Uhlig's (2008) method of applying sign restrictions on selected impulse response functions following a US contractionary monetary shock: "Identification I" in their table 1 requires that  $p_{k_1} \leq 0$ ,  $nbrx_{k_1} \leq 0$ , and  $i_{k_1} \geq 0$ , for  $k_1 = 0, 1, \dots, 11$ , where  $k_1$  denotes months from impact.<sup>7</sup> That is, prices and the non-borrowed reserve ratio are required not to rise and interest rates are required not to fall for 1 year in response to a US contractionary monetary shock. The advantage of the sign restrictions method, as argued by Faust and Rogers (2003), Uhlig (2005), and Scholl and Uhlig (2008), is that it precludes implausible responses of prices and interest rates to a monetary shock. For example, under the recursive identification methods that are used by Eichenbaum and Evans (1995), prices often rise in response to a monetary contraction (the price puzzle) and interest rates often fall in response to a monetary contraction (the liquidity puzzle).<sup>8</sup> While this sign restrictions method helps to avoid such puzzles that exist under the recursive identification methods, it leaves the exchange rate unrestricted and thus our question agnostically open.

With respect to estimation method, we employ the Bayesian VAR procedure by Scholl and Uhlig (2008). We develop a Bayesian VAR with six lags and without a constant term and time trends. Assuming the Normal-Wishart family for the prior, we obtain results by taking draws from the posterior for the VAR coefficients that satisfy the sign restrictions; see Scholl and Uhlig (2008, 4–6) for the details of the estimation procedure and of the identification of monetary shocks. This Bayesian methodology has received some criticism regarding the interpretation of the error bands provided. For instance, Fry and Pagan (2011) indicate that these bands describe uncertainty only across models. However, our Bayesian procedure with a "flat" or "rotation-invariant" prior over the set of all possible impulse vectors in the appropriate orthonormalized space produces

<sup>7</sup> The selection of the horizon of the sign restrictions is arbitrary. However, Scholl and Uhlig (2008) argue that with their identification scheme Identification I, 1 year is a desirable horizon because it conforms to a sensible duration of the liquidity effect and reduces spurious effects.

<sup>8</sup> See Reichenstein (1987), Leeper and Gordon (1992), and Sims (1992) for details.

genuine confidence bands for the identified set of parameters (see Uhlig 2005).

Throughout the paper, we refer to the seven-variable VAR with the sign restrictions described above as the benchmark model.

### III. Empirical Results

Dornbusch's overshooting hypothesis predicts that a currency will appreciate on impact and then gradually depreciate toward its long-run value in response to a contractionary monetary shock. We test this prediction and present the results for the two exclusive subsample periods and for the entire sample period.

#### A. Overshooting

Figure 1 plots the impulse response of the two aggregate real exchange rates to a US contractionary monetary policy shock. Following the convention in the literature, we present the 16, 50, and 84 percent quantiles of the posterior distribution for the points on the impulse response functions based on 5,000 draws. We focus on the behavior of exchange rates and provide the impulse response of other variables in the online supplement. First of all, we observe the following results from the median impulse responses of real exchange rates:

- In the entire sample period, the exchange rates gradually fall and then slowly return to their long-run value (delayed overshooting).
- During the Volcker era, the maximal response of exchange rates is delayed over 20–36 months, similarly to the entire sample (delayed overshooting).

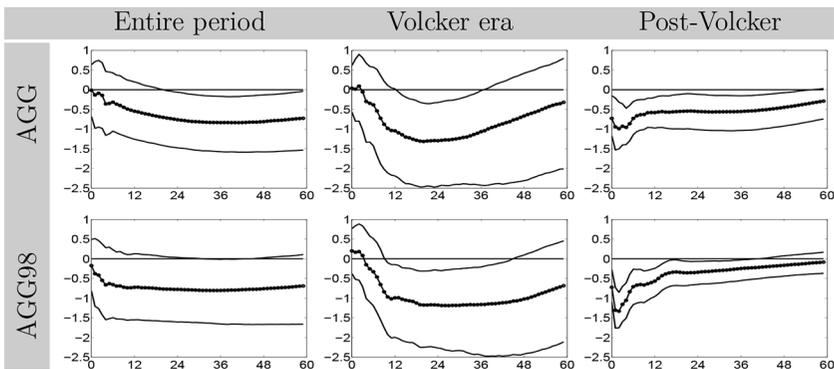


FIG. 1.—Impulse responses of real exchange rates (benchmark model)

- During the post-Volcker era, the maximal appreciation of US real exchange rates occurs within 2 months followed by gradual depreciation (immediate overshooting).

In essence, these results indicate, first, that the delayed overshooting puzzle is substantially reduced in the post-Volcker era and, second, that the puzzle's apparent persistence in the entire sample period is primarily driven by the behavior of exchange rates during the Volcker era. These key results are generally consistent with the behavior of real exchange rates for the individual country pairs.<sup>9</sup>

Figure 2 complements the impulse response analysis: it presents the posterior distribution of the occurrence of the maximal response of real exchange rates (i.e., the distribution of the month with the lowest value of each impulse response drawn from the posterior). During the Volcker era, delayed overshooting behavior is evident for the two aggregate pairs, with the bulk of peak responses occurring between 10 and 50 months. Moreover, the probability of the peak appreciation of US real exchange rates occurring within 3 months remains merely 1 percent, and even that occurring within 6 months remains only 3 percent. During the post-Volcker era, in sharp contrast, the bulk of peak responses occur within 6 months. For example, the probability of the peak response of the US-AGG (US-AGG98) exchange rate occurring within 3 months is 43 percent (70 percent), and the probability of the peak response occurring within 6 months is 76 percent (87 percent). This result is fully consistent across all 14 individual country pairs. In addition, we conduct a *t*-test for the equality of the averages of peak months between the Volcker and post-Volcker eras. At all conventional levels, we decisively reject the hypothesis that the averages are the same between the two subsamples.<sup>10</sup> These results confirm our visual comparison.

Our key findings, on the one hand, are consistent with those of previous empirical studies such as Eichenbaum and Evans (1995) and Scholl and Uhlig (2008) but, on the other hand, are in sharp contrast to their conclusions regarding Dornbusch's overshooting hypothesis: similarly to these studies, the exchange rates exhibit delayed overshooting in the entire sample period; but in contrast to these studies, we find that the observed delayed overshooting behavior is attributed to one particular sample period. Our findings suggest that the very different responses of exchange rates between the Volcker and post-Volcker eras have misled previous empirical studies testing the Dornbusch hypothesis. Although the Volcker

<sup>9</sup> One exception is that the US-JP real exchange rate experiences another large gradual decrease before converging to its long-run value during the post-Volcker era, though it overshoots on impact. See fig. A1 in the Appendix for non-EMU countries and the online supplement for EMU members.

<sup>10</sup> See table TS1 in the online supplement.

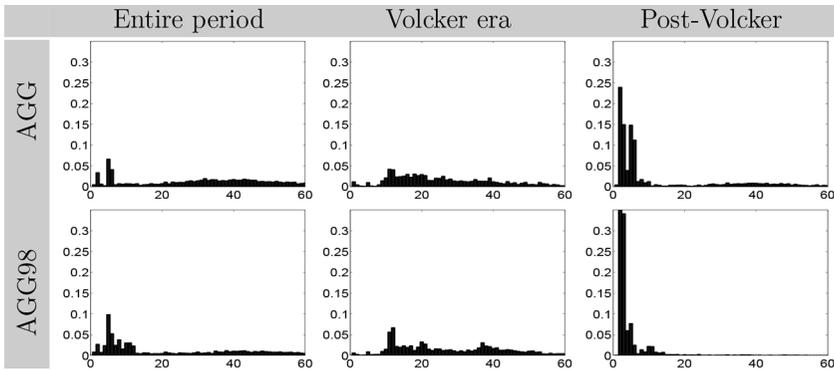


FIG. 2.—Posterior distribution of the timing of the maximal response of real exchange rates (benchmark model).

era represents only one-fourth of the entire sample in terms of the number of observations, its influence is substantial enough to contaminate the results for the entire sample period.

The real and nominal exchange rates behave very similarly at both the aggregate and individual levels.<sup>11</sup> The robustness of the results to the use of real or nominal exchange rates is consistent with previous studies. In addition, the results for both US-AGG and US-AGG98 real exchange rates are very similar. Henceforth, to conserve space, we will report only results for the US-AGG real exchange rates below. Unless indicated otherwise, we will relegate the results for the individual country pairs to the online supplement.

### B. Robustness

We conduct sensitivity analyses in several directions by (i) replacing the US interest rate with the federal funds rate in the benchmark model, (ii) including a constant term in the benchmark VAR, (iii) varying the lag lengths from 3 to 9 months, and (iv) varying the horizon of sign restrictions from 6 to 15 months. Overall, the conclusions from the benchmark model remain unchanged with these variations.<sup>12</sup>

We also conduct robustness exercises under two different identification schemes (sign restrictions vs. recursive identification), each involving various VAR specifications. Overall, we find that the sign restriction

<sup>11</sup> Nevertheless, the immediate overshooting pattern during the post-Volcker era turns out somewhat more pronounced for the real exchange rates than for the nominal exchange rates. Regarding the behavior of aggregate nominal exchange rates, refer to fig. S3 in the online supplement.

<sup>12</sup> See the online supplement for further information.

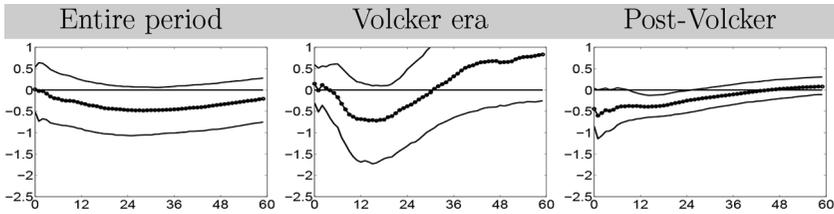


FIG. 3.—Robustness of sign restriction method (an 11-variable model)

method is robust with respect to different specifications and our conclusions from the benchmark model remain unchanged. In contrast, the recursive identification leads to unclear results, which are too sensitive to small variations in VAR specifications and even contradict one another.

Specifically, following Faust and Rogers (2003), we consider an 11-variable VAR model that includes foreign CPI, US and foreign long-term bond rates, and the US commodity price index in addition to the seven variables in our benchmark model.<sup>13</sup> We impose the same sign restrictions as in the benchmark model.<sup>14</sup> Because of the small number of observations relative to the number of variables, we set the lag length to four. As shown in figure 3, the results regarding the peak response of the US-AGG real exchange rates are in general consistent with those from the benchmark model, although the statistical significance is weaker than in the benchmark model.

However, with the recursive identification scheme, the results drawn are not reliable. Specifically, when using the same seven-variable VAR model together with a Cholesky identification following Eichenbaum and Evans (1995), the results obtained when taking the innovations to federal funds rates as US monetary shocks contradict those obtained when taking the innovations to *nbrx* (see fig. 4). In addition, the results are accompanied by liquidity and price puzzles.<sup>15</sup> So it seems more reasonable to see these sensitive results as an additional demonstration of the well-known criticisms about the dubious assumptions underlying the recursive identification.

#### IV. Monetary Policy Effectiveness

We have shown that the behavior of exchange rates conditional on US monetary policy shocks substantially differs between the Volcker era and

<sup>13</sup> We do not include foreign monetary aggregates because of a data availability problem.

<sup>14</sup> We also do robustness checks by imposing the nonpositive sign restriction on the response of the US commodity price index to a US monetary contraction, in addition to the sign restrictions in the benchmark model. The results remain intact.

<sup>15</sup> Refer to the online supplement for details.

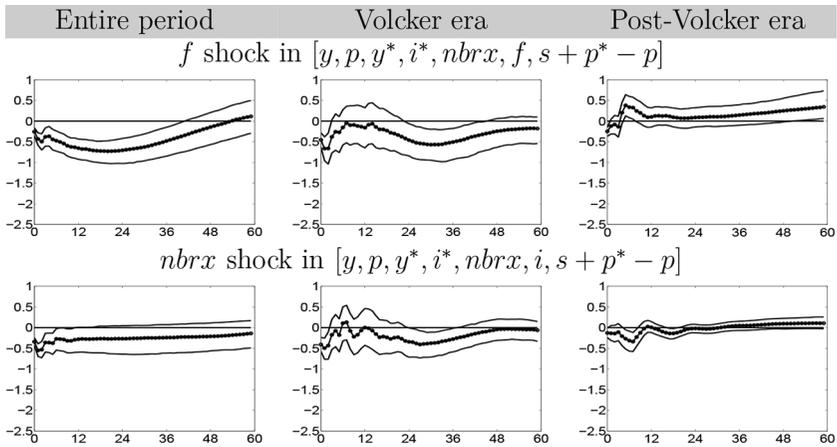


FIG. 4.—Robustness of recursive identification (a seven-variable model)

the post-Volcker era. Further, the behavior of exchange rates during the Volcker era is “extraordinary” and “overwhelming” in the sense that delayed overshooting is primarily observed for that particular period but misleadingly appears to be present throughout the entire sample period. In this section, we provide additional evidence supporting our characterization of delayed overshooting as a phenomenon of the 1980s and demonstrate the importance of distinguishing among monetary policy regimes in an investigation of exchange rate behavior.

#### A. Exchange Rate Variability

We conduct the forecast error variance decomposition for the US-AGG real exchange rate movements explained by a US contractionary monetary policy shock. Three results are immediate from the upper panel of figure 5. The share of the forecast error variance of the aggregate exchange rate attributable to the US monetary shock

- follows the same pattern as its impulse response,
- varies significantly across sample periods, and
- appears to be far smaller than that at the individual country level in each of the two subsample periods.

Specifically, the maximal accountability of the US monetary policy shock occurs over 20–36 months at the median estimate in the Volcker era, around 0–4 months in the post-Volcker era, and throughout the 5-year horizon in the entire sample period. Regarding magnitude, on average, the US monetary policy shock accounts for 12.4 percent of the ex-

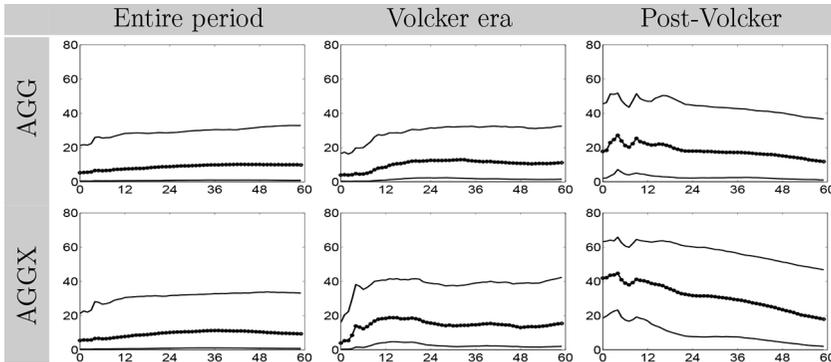


FIG. 5.—Forecast error variance decomposition for real exchange rate fluctuations (benchmark model).

change rate fluctuations over the 20–36-month horizon in the Volcker era and 22.2 percent over the 0–4-month horizon in the post-Volcker era, respectively, and 8.3 percent over the 5-year horizon in the entire sample period.

The first result is obvious in the sense that the time periods of the maximal accountability correspond to those of the maximal impulse response of exchange rates. However, this first result provides an important clue to understanding the second result, which effectively demonstrates the importance of distinguishing among monetary policy regimes and helps to explain the third result. On the basis of the first result, we discuss two related effects that arise when data are pooled for different subsample periods and aggregated across countries. We will then argue that both pooling and aggregation effects mask the true accountability of US monetary shocks.

To understand the third result due to the effect of aggregation, we first compare the individual country pairs to the aggregate for the Volcker era. The maximal accountability occurs over the period from 10 to 48 months for the individual country pairs, which approximately corresponds to the period in which the maximal impulse response occurs (see fig. A1 and fig. A2 in the Appendix). This extensive dispersion in the timing of their maximal accountability can affect the aggregate of individual exchange rate fluctuations attributable to the common US monetary shock. Specifically, the share of the forecast error variance of the US-AGG rate is generally flattened over the 20–36-month horizon and is smaller than the maximum shares of the individual US bilateral rates.<sup>16</sup>

<sup>16</sup> To illustrate this flattening effect of aggregation on the responses to a shock, we consider the following simple example: let  $x_{1t} = a_t + u_t$  and  $x_{2t} = a_{t-1} + u_t$ , with  $a_t$  and  $u_t$

We next confirm more explicitly the aggregation effect for the post-Volcker era. At the individual level, the US-JP case appears to be somewhat exceptional with respect to the timing of the maximal accountability: it occurs at approximately 18 months, which is substantially delayed relative to that for the other country pairs. Such peculiar behavior, which may stem from country-specific factors beyond the scope of this paper, has a significant influence due to the substantial weight of JP in the aggregation. To observe this aggregation effect more explicitly, we consider another representative aggregate by removing JP from the rest of the world and naming it AGGX. As shown in the lower panel of figure 5, the magnitude of the accountability of US monetary policy shocks increases dramatically: It accounts for 43.2 percent of the US-AGGX exchange rate fluctuations, on average, over the 0–4-month horizon at the median estimate, which is twice as large as the case for the US-AGG rate. Apart from the US-JP rate, the aggregation effect is small in the post-Volcker era, as the periods of the maximal accountability that correspond to those of the maximal impulse response all remain within a small interval: 0–4 months for individual country pairs.

Bearing this aggregation effect in mind, we now examine the second result by investigating the effect of pooling the two subsample periods. As shown in figure 5, the magnitude of the US-AGG real exchange rate fluctuations is very small in the entire sample period, supporting the results in Scholl and Uhlig (2008). However, the accountability of the US monetary shock is substantial at the 0–4-month horizon in the post-Volcker era but at the 20–36-month horizon in the Volcker era. Because of this extensive dispersion in the timing of the maximal accountability across the subsample periods, the exchange rate fluctuations cancel one another out in the pooled sample. Thus, the maximal accountability of the US monetary shock in the entire sample period is flattened throughout the 5-year horizon and is smaller than that in each of the subsample periods. This pattern also holds for the US-AGGX rate: the US monetary shock accounts for 9.4 percent of the exchange rate fluctuations, on average, over the 5-year horizon in the entire sample period.

This pooling effect is also present for each of the individual country pairs and explains why previous studies have reported a wide range of

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white noise, uncorrelated at all lags, and  $\sigma_a = \sigma_u$ ; and construct their aggregate given by

$$x_t = \frac{1}{2}(x_{1t} + x_{2t}) = \frac{1}{2}(a_t + a_{t-1}) + u_t = \frac{1}{2}(1 + L)a_t + u_t,$$

where  $L$  is the lag operator. Then, the forecast error variance contribution of  $a_t$  amounts to 50 percent for each individual series  $x_{1t}$  and  $x_{2t}$  at any horizon larger than zero, but only 33 percent for the aggregate  $x_t$ . A similar result can be found when pooling several regimes with different dynamics. We thank an anonymous referee for providing us with this example.

the estimates for the share of exchange rate fluctuations attributable to US monetary policy shocks. For example, using monthly data from 1974:1 to 1990:5 during which the delayed overshooting appears to be most prominent, Eichenbaum and Evans (1995) report that US monetary policy shocks account for approximately 42, 26, and 23 percent of the exchange rate fluctuations for the US-GE, US-UK, and US-JP country pairs, respectively, at lags 31–36 (see also Clarida and Gali 1994). However, using monthly data from 1975:7 to 2002:7, a coverage period that nearly overlaps with our entire sample period, Scholl and Uhlig (2008) report a share of approximately 10 percent for the same countries at the same lags.

In brief, US monetary policy shocks account for a significant share of exchange rate fluctuations. In particular, they have a substantial and immediate impact on exchange rate fluctuations during the post-Volcker era. This result is in stark contrast with those of previous studies. Thus, if one ignores the history of US monetary policy regimes and pools them all together, US monetary shocks misleadingly appear to have a small impact on exchange rate fluctuations.

*B. Serial Dependence of Exchange Returns*

If the monetary policy regime underlies the behavior of exchange rates and truly matters, it can be inferred that not only the conditional response of exchange rates to monetary shocks but also the unconditional average response of exchange rates to all possible shocks will show distinguishable movements between monetary policy regimes. In other words, if unconditional exchange rate movements inherit this conditional behavior, changes in exchange rates will exhibit strong, positive serial dependence during the Volcker era that reflects delayed overshooting behavior. We test this prediction with the variance ratio test for the serial dependence of exchange returns over long horizons.<sup>17</sup>

We define the population variance ratio  $VR(q)$  by

$$VR(q) = \frac{\text{Var}\left(\sum_{l=0}^{q-1} \xi_{t+l}\right)}{q \text{Var}(\xi_t)} = 1 + 2 \sum_{l=1}^{q-1} \left(1 - \frac{l}{q}\right) \gamma(l),$$

where  $\xi_{t+l}$  denotes the change in exchange rates between period  $t + l - 1$  and  $t + l$ ;  $q$  an accumulation horizon; and  $\gamma(l) = \text{Cov}(\xi_t, \xi_{t+l})/\text{Var}(\xi_t)$  the autocorrelation of exchange rate returns between  $t$  and  $t + l$ . The ratio  $VR(q)$  must be equal to one for each  $q$  if the returns are not serially correlated. If the returns are positively (negatively) autocorrelated,  $VR(q)$  should be greater (less) than one.

<sup>17</sup> For information on tests for serial dependence over long horizons, refer to Fama and French (1988) and Moon and Velasco (2013), among others.

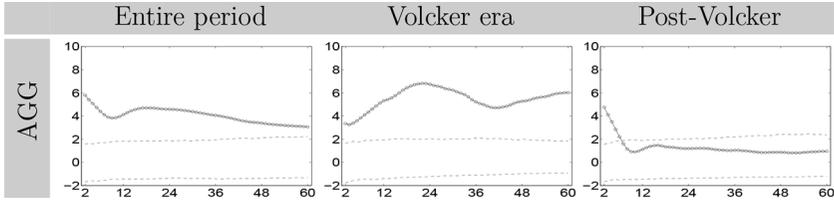


FIG. 6.—Serial dependence of changes in real exchange rates

Figure 6 shows the evolution of the  $t$ -values of the estimated variance ratios with respect to  $q$  over a 5-year horizon. During the Volcker era, the  $t$ -values are all positive and substantially greater than the critical values at the 95 percent quantile of the empirical distribution throughout the 5-year horizon; further, the locus of  $t$ -values with  $q$  is hump shaped, having a peak between 18 and 36 months.<sup>18</sup> These two features are consistent with the implications of delayed overshooting behavior. In contrast, in the post-Volcker era, one can no longer observe a hump-shaped pattern of serial dependence: The  $t$ -values of the estimated variance ratios are largest at 2 months. Then, they rapidly decrease and remain inside the band with the critical values at the 5 percent and 95 percent quantiles for every  $q$  beyond 6 months in the post-Volcker era. In the entire sample period, the  $t$ -values are all positive throughout the 5-year horizon and far above the critical values at the 95 percent quantile. Further, the locus of the  $t$ -values looks hump shaped following a modest decrease in earlier months, indicating that the unconditional exchange rate behavior is also significantly influenced by the Volcker era.

In sum, the contrasting behavior of unconditional exchange rates between the Volcker era and the post-Volcker era closely resembles that of conditional exchange rates in response to US monetary policy shocks in that (i) the behavior in the Volcker era is distinct from that in the post-Volcker era and (ii) the influence of the Volcker era is so strong that pooling all subsample periods together can provide a misleading understanding of the true exchange rate behavior. Ultimately, the fact that the serial dependence pattern of unconditional exchange returns in the Volcker era is consistently characterized by delayed overshooting suggests that conditional and unconditional exchange rate movements are closely linked. Provided that no structural breaks occur in the processes that generate all other shocks, the behavior of unconditional real exchange returns highlights the importance of distinguishing among monetary policy regimes.

<sup>18</sup> We conduct our inference by using a wild bootstrap method to improve the finite sample properties of the variance ratio test based on Moon and Velasco (2013).

**V. Uncovered Interest Parity**

We have shown that Dornbusch’s overshooting hypothesis mainly fails to hold in the Volcker era but tends to hold in the post-Volcker era. We now provide an explanation for this finding. A natural starting point is to examine the connection between the hypothesis’s predictions and its key assumptions. Among the assumptions, we focus on UIP: It states that a currency with a higher interest rate will depreciate. If UIP holds, the US dollar should depreciate following immediate appreciation in response to a US contractionary monetary shock that leads to a higher US interest rate relative to the foreign interest rate. In this section, we investigate whether the subsample periods also significantly differ in terms of deviations from UIP. Overall, we find that the UIP assumption significantly fails during the Volcker era, when the overshooting hypothesis also fails; however, it tends to hold elsewhere when immediate overshooting also occurs. This new evidence supports the theory of exchange rate movements built on the UIP assumption and thus demonstrates that the delayed overshooting puzzle is a phenomenon of the 1980s.

*A. Conditional UIP*

We begin with conditional UIP in response to a monetary policy shock. Let us consider the following trading strategy in response to a US contractionary monetary shock: An investor borrows in foreign currency for  $k$  months, exchanges it for the US dollar, holds US Treasury bills for  $k$  months, and exchanges the interest rate returns on the US dollar back for the foreign currency  $k$  months later. The return from this strategy from  $j$  to  $j + k$  is defined by

$$\rho_{j+k} = \frac{1,200}{k} (s_j - s_{j+k}) + i_{j|k} - i_{j|k}^*, \tag{1}$$

where  $s_j$  is the impulse response of the nominal exchange rate in period  $j$ , and  $i_{j|k}$  ( $i_{j|k}^*$ ) is the impulse response of  $k$ -month US (foreign) interest rates. We multiply  $s_j - s_{j+k}$  by  $1,200/k$  to obtain annualized returns from this trading strategy. The cumulated returns from period 0 to period  $T$  can be defined by

$$\rho^T = \sum_{l=0}^{T/k-1} \rho_{lk+k}.$$

Conditional UIP in our VAR analysis states that  $\rho_{lk+k} = 0$  for all  $l$  and thus  $\rho^T = 0$ , under which the gain from the interest rate difference and the loss from the currency exchange should offset one another. Conversely, if the US dollar tends to persistently appreciate when the US interest rate is higher, the trading strategy will yield a positive gain with certainty from

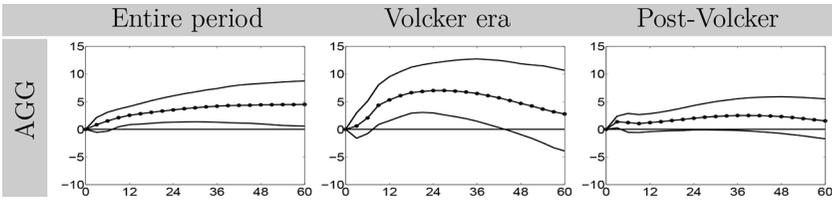


FIG. 7.—Conditional UIP: cumulated impulse responses of 3-month excess returns (benchmark model).

the interest rate difference as well as a positive average capital gain from the currency exchange.

Figure 7 depicts the impulse responses of cumulated excess returns from the above trading strategy with the 3-month holding period ( $k = 3$ ), as our study uses 3-month interest rates. Note that to calculate excess returns, we replace real exchange rates with nominal exchange rates in our VAR specification. In the entire sample period, the cumulated excess returns are positive over the 5-year horizon in line with Scholl and Uhlig (2008). However, this behavior is driven by one particular sample period, the Volcker era: The cumulated excess returns are positive over most of the horizons during the Volcker era but remain close to zero over most of the horizons in the post-Volcker era, suggesting that conditional UIP is significantly violated during the Volcker era but tends to hold in the post-Volcker era. Furthermore, by implication, previous studies arguing for the failure of conditional UIP may have been misled by not distinguishing the impacts of the Volcker era.

### B. Unconditional UIP

We now turn to testing unconditional UIP. We investigate whether, similar to conditional UIP, unconditional UIP tends to hold in the periods of immediate overshooting and does not hold in the periods of delayed overshooting. In doing so, our tests of unconditional UIP provide clues regarding the sources of the deviations from UIP, which have long been sought in the literature on the forward premium anomaly.<sup>19</sup>

We test unconditional UIP by examining the predictability of excess returns between time  $t$  and  $t + k$  defined by  $s_t - s_{t+k} + i_{t|k} - i_{t|k}^*$ .<sup>20</sup> Under the assumptions of rational expectations and risk neutrality, UIP implies no predictability of excess returns with the use of any variables in the cur-

<sup>19</sup> See Lewis (1995) and Engel (1996) for the survey.

<sup>20</sup> Here we use subscript  $t$  to denote a data point because unconditional excess returns are calculated directly from the data, whereas in (1) we use subscript  $j$  to denote a point in the analysis horizon because conditional excess returns are calculated from our VAR model.

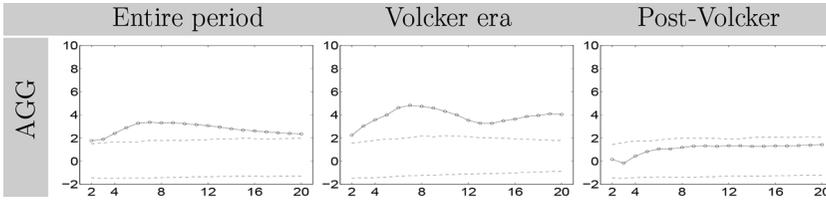


FIG. 8.—Unconditional UIP: Serial dependence of 3-month excess returns

rent information set. To test this, we use the variance ratio test with some modification: Our previous variance ratio test in Section IV.B tested the null hypothesis that real exchange rates follow a random walk. Here, the null hypothesis for the test of unconditional UIP is that  $k$ -period excess returns are not predictable. As data frequency (monthly) is finer than the forecasting interval ( $k$  months), we need to account for the moving average structure of forecasting errors for the variance ratio test. We adopt the sample splitting method developed by Moon and Velasco (2013).

Figure 8 presents the serial dependence of excess returns over a 5-year horizon. Note that because we are testing the predictability of 3-month excess returns, the unit of  $q$  is now a quarter. During the Volcker era, the  $t$ -values of estimated variance ratios are all positive and much greater than the critical values at the 95 percent quantile of the empirical distribution throughout the horizon; further, the locus of  $t$ -values with  $q$  is hump shaped, having a peak between five and 10 quarters. This positive serial dependence pattern further indicates that predictable components in excess returns are not mean reverting. In contrast, in the post-Volcker era, the  $t$ -values remain inside the band with the critical values at the 5 percent and 95 percent quantiles, suggesting that excess returns are unpredictable. In the entire sample period, the  $t$ -values are all positive and above the critical values at the 95 percent quantile, indicating that deviations from UIP are significantly influenced by the Volcker era. These patterns of serial dependence across the subsample periods suggest that the conditional and unconditional movements of excess returns are closely linked. Again, provided that no structural breaks occur in the processes that generate all other shocks, the behavior of unconditional excess returns highlights the importance of distinguishing among monetary policy regimes.

Our result is compatible with the well-known empirical regularity called the forward premium anomaly, at least with respect to existing studies including the 1980s in their sample periods. To facilitate a comparison between our study and previous studies, we also consider the most popular test for UIP in the literature and run a regression of the excess return on the interest rate difference:

$$s_{t+k} - s_t - i_{t|k} + i_{t|k}^* = \alpha + \beta(i_{t|k} - i_{t|k}^*) + u_{t+k}, \tag{2}$$

TABLE 1  
EXCESS RETURN REGRESSION

	ENTIRE PERIOD			VOLCKER ERA			POST-VOLCKER ERA		
	$\hat{\beta}$	$t$	$R^2$	$\hat{\beta}$	$t$	$R^2$	$\hat{\beta}$	$t$	$R^2$
AGG	-2.45	-3.05	.03	-5.66	-2.44	.13	-2.18	-2.29	.02
AGGX	-1.94	-2.10	.01	-5.84	-2.40	.11	-1.71	-1.51	.01

NOTE.—AGG refers to the seven non-EMU countries plus GE prior to 2008; AGGX refers to AGG excluding JP.  $t$  is the  $t$ -value of the estimate in regression (2).

where  $\alpha = 0$  and  $\beta = 0$  under UIP. Table 1 reports the regression results for each sample period.<sup>21</sup> In the entire sample period, the conventional  $t$ -test rejects the UIP hypothesis. It does so also in the Volcker era. Although we reject the null in the post-Volcker era, the significance is substantially reduced when we exclude the US-JP exchange rate. Moreover, the explanatory power of the interest rate difference, measured by  $R^2$ , is nearly zero in the post-Volcker era, which is in sharp contrast with the magnitude of 0.13 observed in the Volcker era. Furthermore,  $\hat{\beta}$  (in absolute value) is far greater in the Volcker era than in the post-Volcker era.<sup>22</sup> Overall, similar to conditional UIP, unconditional UIP dramatically fails in the Volcker era, whereas the violations of unconditional UIP are much weaker in the other subsample period. By implication, the Volcker era significantly contributes to the development of the forward premium anomaly.

Finally, we employ Bai and Perron's (2003) structural break tests for the abrupt changes in the mean of excess returns. We find that either two or four breaks occur over the entire sample period depending on the test and the aggregate considered.<sup>23</sup> In all cases, the estimated break dates include 1980:9 and 1985:6. This result is broadly consistent with our sample division. More strikingly, these break dates coincide with both a period of persistent appreciation of the US dollar in the 1980s (the left panel of fig. 9) and a period of a historically high difference between the long-term interest rate and inflation (the right panel of fig. 9). Bearing in mind that the persistent appreciation is a common feature underlying delayed over-

<sup>21</sup> Here, we calculate aggregate excess returns and the corresponding interest rate differences between the United States and its trading partner by the GDP-weighted averages of individual excess returns and interest rate differences, following the convention in the literature of the forward premium anomaly. So an aggregate excess return is interpreted as a GDP-weighted portfolio. We also consider those variables constructed by the aggregation method in the Appendix. The results are very similar between the two methods, suggesting robustness of our results along this direction.

<sup>22</sup> This result is consistent with that of Moon and Velasco (2012), who considered 1-, 3-, 6-, and 12-month forward exchange rates and found that significant deviations from UIP primarily occur in the 1980s.

<sup>23</sup> We relegate the details to table TS2 in the online supplement. The Matlab files for running the tests are obtained from Pierre Perron's webpage.

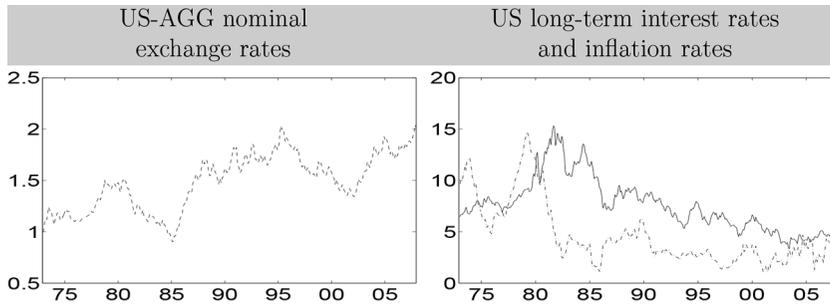


FIG. 9.—Nominal exchange rates, long-term interest rates, and inflation rates

shooting and a violation of UIP, we turn in the next section to an explanation for our empirical findings presented so far.

**VI. Incredible Volcker Disinflation**

We have documented the conditional behavior of exchange rates following US monetary policy shocks over three sample periods including two mutually exclusive subsample periods and have established that delayed overshooting is primarily a phenomenon of the Volcker era. We have also shown that both conditional and unconditional UIP are significantly violated only during the Volcker era. Furthermore, we have shown that the unconditional exchange rate movement in terms of serial dependence of exchange returns over long horizons is distinct in the Volcker era and closely reflects delayed overshooting behavior. Finally, we have demonstrated that simply examining the entire sample period leads to an erroneous conclusion regarding the true behavior of exchange rates, as the effect of the Volcker era dominates the effects of the other sample periods. In this section, we examine why the Volcker era has such extraordinary and overwhelming impacts.

We regard the imperfect credibility of the Volcker Fed’s disinflation policy in the early 1980s as a primary reason for the violations of both the overshooting hypothesis and UIP. We begin with historical episodes and evidence from this period, based on the analysis of Goodfriend (2005) and Goodfriend and King (2005). At its onset, the Volcker Fed’s disinflation plan was not considered to be credible by contemporary observers in the late 1970s and early 1980s. Over the two decades prior to Volcker’s chairmanship at the Fed, the annual pace of inflation rose by more than tenfold from below 1 percent to above 10 percent, albeit with some fluctuations. The generation-long inflation and a series of adverse real shocks in the 1970s created the public perception that inflation was a permanent phenomenon. In addition, there was consensus that disinflation could be costly yet be accompanied by large unemployment in the

short run.<sup>24</sup> The long-standing impression of inevitable inflation and costly disinflation is one of the reasons that made the Volcker Fed's goal appear not to be credible.

Moreover, the early course of the Volcker Fed led to a further loss of credibility concerning the disinflation plan. Volcker himself, near the beginning of his tenure as chairman, repeatedly promised monetary tightening in hearings. Further, the Volcker Fed clearly indicated that it at least intended to slow the pace of inflation if it were unable to immediately achieve disinflation. Unfortunately, despite their anti-inflation stance, the economy experienced rapid inflation, reaching 14.6 percent (record high postwar CPI inflation) in March 1980. The Fed's reaction to this inflation was aggressive, increasing the federal funds rate to 17.6 percent in April 1980. However, by that point, the signs of a recession were already becoming clear. In response to this recession, the Fed made its first policy "U-turn" by cutting the federal funds rate by approximately 8 percentage points in the subsequent months. This substantial swing in policy at the first signs of recession made discerning the true intentions of the Volcker regime increasingly difficult for the public.

The US economy experienced another recession between late 1981 and 1982. On the other hand, the public observed that inflation had been curbed to a rate of 4 percent by late 1982 (annual percentage change of CPI)—the first observation of inflation in the 4 percent range since March 1973. We now know that this moment was truly remarkable because from that point onward, US inflation was consistently contained within a range of 1.5–4.5 percent throughout the Volcker Fed's remaining tenure (and even beyond). However, for the public of late 1982, these events had yet to occur in the future. The 10-year Treasury bond rate reacted little to the massive decline in inflation experienced during the 1981–82 recession, rather elevated from 10 percent in mid-1983 to over 13 percent in mid-1984 and remained above 10 percent until October 1985. This delayed reaction to inflation on the part of nominal bond returns led to a historically high difference between the long-term interest rate and inflation during the 1982–85 period, which was three times higher, on average, relative to the entire postwar period (see the right panel of fig. 9). Goodfriend (2005) attributes this divergence to an "inflation scare."<sup>25</sup> Both the magnitude and the duration of this difference indicate that the public was continuously expecting a return to a high-inflation regime: That is, the Volcker Fed's disinflation plan was not considered credible. The Fed was also

<sup>24</sup> See, e.g., Okun's (1978) survey on the estimates of Phillips curves.

<sup>25</sup> In fact, Goodfriend (2005) identifies four distinct inflation scares for the Volcker era, each rising in 1980, 1981–82, 1983–84, and 1987. He regards the fourth scare occurring in the last year of Volcker's chairmanship as "striking evidence of the fragility of the credibility of the Fed's commitment to low inflation" (249). In short, the credibility problem was persistent throughout Volcker's entire mandate.

aware of the public's mind: "We've had a heck of a difference in the interest rate structure since '79, in those terms, which one can interpret as the American people giving up on the idea that we were ever going to return to price stability," Volcker remarked (Federal Open Market Committee 1981, 39).

This perceived possibility of a monetary policy U-turn under the Volcker Fed may have triggered the persistent appreciation of the US dollar between 1980 and 1985. For instance, in Gourinchas and Tornell (2004), the adjustment of exchange rates can be protracted when the public underestimates the effective horizon of a contractionary monetary shock. And this underestimation can generate expectational errors that are sufficiently large to explain both the delayed overshooting and the forward premium puzzles. Briefly to map the 1980s to the model world of Gourinchas and Tornell, the credibility problem facing the Volcker Fed is written in terms of a gap between the true and the perceived persistence of interest rate shocks. Agents living in their model world who perceive a (nearly) permanent rise in the home interest rate as a temporary one are a narrative of the public who expected the Volcker Fed to U-turn to inflationary policy. Given their misperception, agents underreact to a contractionary monetary shock because they weight between a new piece of observation and their previous beliefs. And the home currency appreciates on impact, but only to an extent that is consistent with agents' held weight on the new observation. If the home interest rate does not revert as quickly as expected in the next period (i.e., remains higher than believed), agents revise their beliefs about the persistence of interest rate shocks and the home currency appreciates again to an extent that is consistent with the weight on an unexpected higher interest rate. Along the path in which the agents' beliefs are updated toward the true intention of the central bank, the delayed overshooting pattern emerges.

The tremendous credibility problem facing the Volcker Fed may also explain why the effects of the Volcker era are so overwhelming that both the conditional and unconditional behaviors of exchange rates in the entire sample period appear to be quite similar to those in the Volcker era. Two of our results help elucidate this phenomenon: (i) the strong positive serial dependence of real exchange returns over long horizons during the Volcker era (fig. 6) and (ii) the strong positive serial dependence of 3-month excess returns over long horizons during the Volcker era (fig. 8). These results show that both returns exhibit qualitatively the same pattern of serial dependence and that they may contain a common, nonstationary trend component.<sup>26</sup> Indeed, the behavior of US long-term

<sup>26</sup> Obviously, returns will exhibit negative serial dependence over long horizons if they contain a stationary predictable component. See, e.g., Fama and French (1988) and Moon and Velasco (2012, 2013). Moon and Velasco (2012) present further evidence using weekly 3-, 6-, and 12-month excess returns: It is only in the Volcker era that the augmented Dickey-

bond rates during the 1980s provides a clue to the presence of the trend component in the returns. As discussed above, the long-term bond rates indicate that market participants continued to expect a policy U-turn between 1980 and 1985, despite the massive monetary contraction. This long-lived imperfect credibility may have generated substantial expectational errors and thus induced the trend of the US dollar appreciation during this period, which is the common feature underlying delayed overshooting and a violation of UIP.<sup>27</sup>

Finally, it may be worth noting that the US-AGG nominal exchange rate has experienced several swings between persistent appreciation and depreciation phases (and so has the real exchange rate, as is well known), including two particularly large ones. Each swing forms a deep and wide valley: one having a trough at 1985 during the Volcker era and the other between the mid-1990s and the mid-2000s in the post-Volcker era. As depicted in the left panel of figure 9, the two valleys look strikingly similar in terms of depth and width. However, in the right panel, both the magnitude and the duration of the difference between the long-term interest rate and inflation confirm that the two valleys were created through totally different mechanisms. We observe their largest difference during the 1982–85 period out of the entire post-Bretton Woods sample. But we have not yet observed significant evidence that monetary policy was regarded as incredible during the post-Volcker era. To the extent that the imperfect credibility of monetary policy is a primary source of expectational errors, our story can explain both the delayed overshooting and UIP violations during the Volcker era and the immediate overshooting and UIP during the post-Volcker era.

## VII. Conclusions

We have reinvestigated the delayed overshooting puzzle and have obtained several new empirical facts. First, using sign restrictions similar

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Fuller test does not reject the unit root hypothesis and the Kwiatkowski-Phillips-Schmidt-Shin test rejects the stationary hypothesis.

<sup>27</sup> Numerous studies have investigated the trend path of US bilateral rates during the 1980s. For example, on the basis of the assumption of heterogeneous expectations, Frankel and Froot (1990) consider the possibility of speculative bubbles. In their model, the market expectation is formed on the basis of the weighted average of forecasts by fundamentalists and chartists, and this weight is updated on the basis of a Bayesian rule regarding the past performance of these two agents. They show that the weight in the market expectation gradually shifts from the fundamentalists' forecasts to the chartists' forecasts during the 1980–85 period, as the forecasts of the fundamentalists continuously turned out to be wrong and a speculative bubble arose as a result. Even if the (exogenously given) chartists' forecasts are consistent with the US dollar appreciation path, their model takes the initial US dollar appreciation path as given for a bubble to emerge. Engel and Hamilton (1990) and Lewis (1989) also model a peso problem and rational learning, respectively, to explain the large swings in the US dollar during the 1980s.

to Scholl and Uhlig's (2008), we find that delayed overshooting is primarily a phenomenon of the 1980s when the Fed was under the chairmanship of Paul Volcker. Second, UIP fails to hold in the 1980s but tends to hold elsewhere. These results support Dornbusch's (1976) overshooting hypothesis. Third, US monetary policy shocks have substantial impacts on exchange rate fluctuations but appear to have small impacts when the subsample periods are pooled. This result suggests that the monetary policy regime itself is central to the explanation of exchange rate fluctuations attributable to monetary policy shocks. Fourth, the Volcker era shows strong delayed overshooting of exchange rates and a positive hump-shaped pattern of serial dependence of exchange returns. This result suggests that unconditional exchange rate movements inherit conditional responses to monetary policy shocks. Connecting all these results to derive a single consistent explanation, we conclude that exchange rate movements and UIP are as cohesively related in data as they are in theory.

We highlight credibility as a possible reason to explain that the Volcker era is so different and influential relative to other periods. To the extent that credibility matters in economic dynamics, we hope this lesson can advance the study of policy in general. Possible research areas include the international transmission mechanisms of economic policy. For example, while acknowledging the need for rigorous analysis including all details of transmission mechanisms, such as trade balance movements, we argue that future research should emphasize the importance of monetary policy regimes when assessing the impact of a home country's monetary policy on foreign welfare. If a central bank's credibility affects the timing and size of market responses to shocks, its credibility will also affect the relative dominance of various transmission channels, such as expenditure switching, income absorption, and world demand effects. Whether to beggar thy neighbor or to beggar thyself would rely on how credible thou art.

**Appendix**

*Data Sources*

TABLE A1  
DATA SOURCES

Variable	Description	Source
$y$	Index of US industrial production	IFS line 66
$y^*$	Index of foreign industrial production	IFS line 66
$p$	US consumer price index	IFS line 64
$p^*$	Foreign consumer price index	IFS line 64
$i$	US Treasury bill rate	IFS line 60c
$f$	Federal funds rate	IFS line 60b

TABLE A1 (*Continued*)

Variable	Description	Source
$i^*$	Foreign short-term interest rate	IFS line 60b or 60c
$nbrx$	US nonborrowed reserves plus extended credit/total reserves	Fed. Reserve Bank St. Louis
$s$	Nominal exchange rate in dollars per foreign currency	Fed. Reserve Bank St. Louis
$s - p + p^*$	Real exchange rate per foreign goods	

NOTE.—We use Treasury bill rates if short-term interest rates are not available for  $i^*$ .

#### *Aggregation Method*

For constructing aggregates, we follow the method by Scholl and Uhlig (2008). First, we calculate weight for each country by dividing the country's GDP by the total GDP at purchasing power parity values. Second, we take growth rates for each individual country. Third, the aggregate growth rates are calculated by the weighted sum of the individual growth rates. Finally, the levels are calculated by cumulating aggregate growth rates from the initial base year. Refer to the supplementary materials online for the replication of our results.

#### *Results for Individual Country Pairs*

The following figures show two key results for non-EMU countries and GE, which are used in the construction of the aggregates based on AGG. We relegate the results for EMU countries to the online supplement.

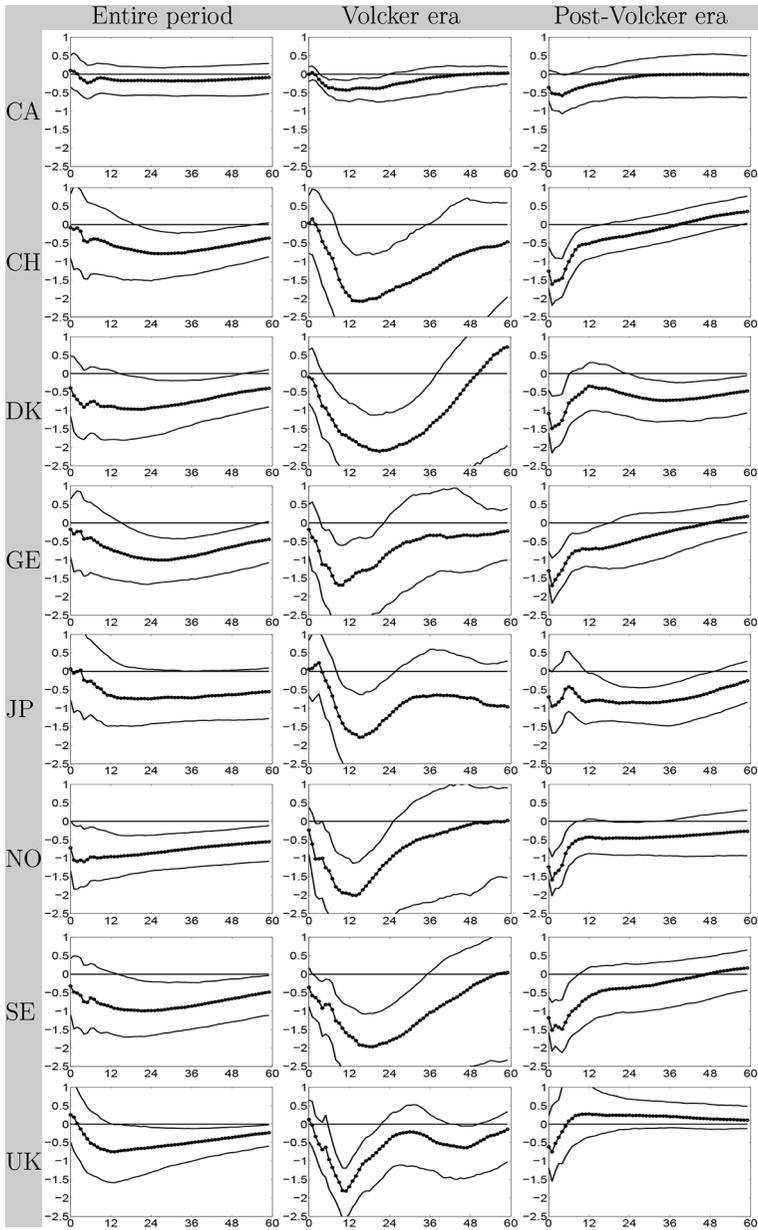


FIG. A1.—Impulse responses of real exchange rates (individual country pairs)

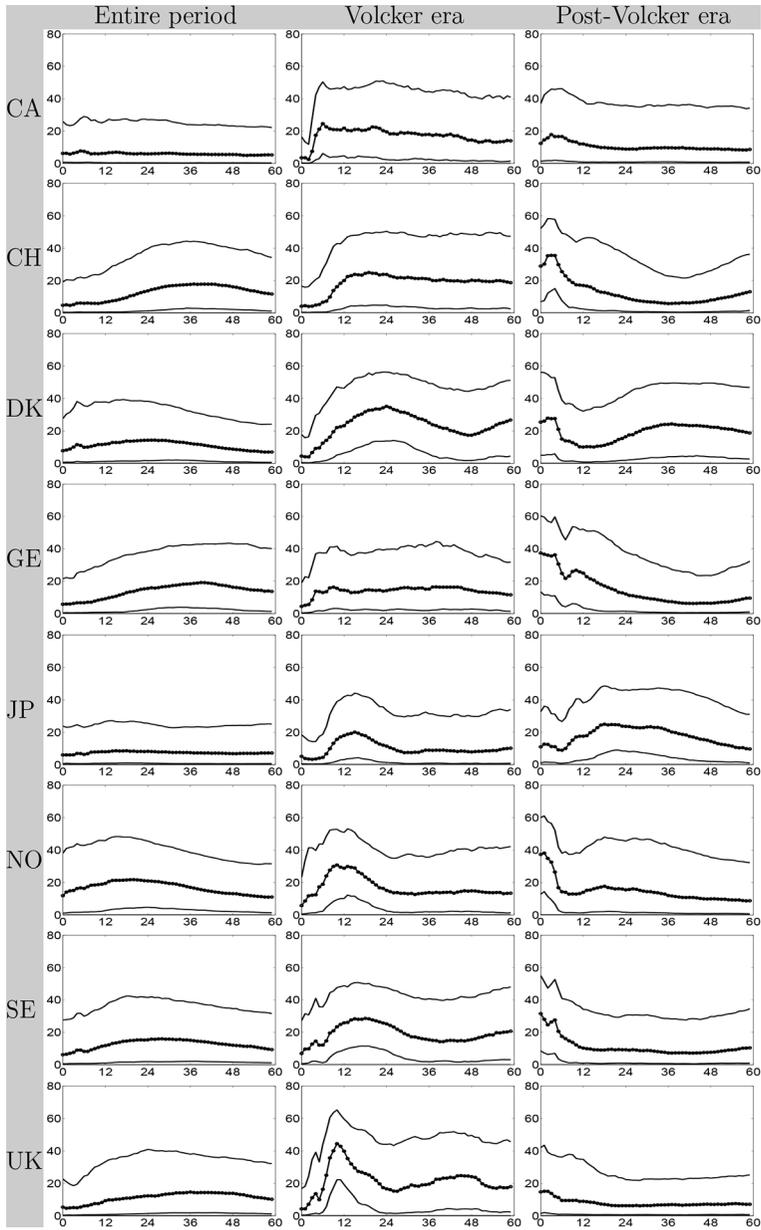


FIG. A2.—Forecast error variance decomposition for real exchange rate fluctuations (individual country pairs).

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