FIXING EXCHANGE RATES: A Virtual Quest for Fundamentals

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Abstract
Fixed exchange rates are less volatile than floating rates. But the volatility of macroeconomic variables such as money and output does not change very much across exchange rate regimes. This suggests that exchange rate models based only on macroeconomic fundamentals are unlikely to be very successful. It also suggests that there is no clear tradeoff between reduced exchange rate volatility and macroeconomic stability.

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Running Headline: Fixing Exchange Rates

An Introduction and Some Motivation

It is clear that exchange rate volatility is costly; expensive and enduring institutions have been developed to combat exchange rate volatility. Currently, most countries in the world manage their exchange rates in some way, and indeed this has been the norm throughout the twentieth century. Why do most countries control their exchange rates? When exchange rates are ignored by central banks, they are typically extremely volatile; when exchange rates are managed, much of this volatility vanishes. Fixing the exchange rate "fixes" the "problem" of exchange rate volatility. This paper is motivated by the question: What happens to the volatility? Most models of exchange rate determination argue that this volatility is merely transferred to other economic loci; i.e., there is "conservation of volatility". For instance, monetary models of the exchange rate imply that stabilization of the exchange rate is achieved at the cost of a more volatile money supply. In this paper, we argue empirically that the volatility is not in fact transferred to some other part of the economy; it simply seems to vanish. When (nominal) exchange rates are stabilized, there do not appear to be systematic effects on the volatility of other macroeconomic variables. This result is intuitively plausible: the volatility of variables such as money and output does not appear to be significantly different during regimes of fixed and floating exchange rates, and is rarely considered to be different by empirical macroeconomic researchers.

If exchange rate stability can be bought without incurring the cost of other macroeconomic volatility, then floating exchange rates may be excessively volatile. Countries that choose not to manage their exchange rates, implicitly allow exchange rate turbulence to persist when it could be reduced with few apparent effects on volatility of other macroeconomic variables. However, it is not possible to make any policy recommendations in the absence of a model that *can* explain exchange rate volatility.

Our primary objective in this paper is to study the implications of exchange rate volatility in regimes of fixed and floating rates for typical OECD countries. However, we also seek to make a methodological contribution, by developing a technique that allows economists to identify potential fundamental determinants of exchange rates. Economists typically model exchange rates as linear functions of fundamentals. It is indisputable that conditional exchange rate volatility depends dramatically on the exchange rate regime. We argue that this fact can be used to distinguish potentially interesting exchange rate models from non-starters that are doomed to have little empirical content.

Suppose that the structural-form linking fundamentals to exchange rates does not change dramatically across regimes, as is true in many theoretical models. The conditional volatility of a typical exchange rate rises dramatically when a previously fixed exchange rate begins to float. *Any potentially valid exchange rate fundamental determinant must also experience a dramatic increase in conditional volatility when a previously fixed exchange rate is floated.* As we shall see, the empirical relevance of this point is particularly strong, since it depends only on structural equations, rather than reduced-forms with possibly unstable coefficients. Empirically, we cannot find macroeconomic variables with volatility characteristics that mimic those of OECD exchange rates even approximately. Intuitively, if exchange rate stability varies across regimes without corresponding variation in macroeconomic volatility, then macroeconomic variables will be unable to explain much exchange rate volatility. Thus existing models, such as monetary models, do not pass our test; indeed, this is also true of any potential model that depends on standard macroeconomic variables. We are driven to the conclusion that the most critical determinants of exchange rate volatility are not macroeconomic.

The following section of the paper lays out the theory and methodology for the analysis that follows. The data is then presented in section IIa (sub-sections IIb-IIc can be skipped without losing the thread of our main argument). The core of the paper is section III, which presents our basic empirical results. The paper ends with a brief conclusion.

I: The Theory and Methodology

Monetary models of the exchange rate are natural choices for our study, since they are simple and conventional. But we hope to show that the thrust of our analysis is much more general.

Ia: Virtual and Traditional Fundamentals for the Flexible-Price Monetary Model

The generic monetary exchange rate model begins with a structural money-market equilibrium condition, expressed in logarithms as:

$$m_t - p_t = \beta y_t - \alpha i_t + \varepsilon_t \qquad (1)$$

where: m_t denotes the (natural logarithm of the) stock of money at time t; p denotes the price level; y denotes real income; i denotes the nominal interest rate; ε denotes a well-behaved shock to money demand; and α and β are structural parameters.

We assume that there is a comparable equation for the foreign country, and that domestic and foreign elasticities are equal. Subtracting the foreign analogue from (1) and solving for the price terms, we have:

$$(p-p^*)_t = (m-m^*)_t - \beta(y-y^*)_t + \alpha(i-i^*)_t - (\varepsilon-\varepsilon^*)_t. \qquad (1')$$

If we assume that prices are perfectly flexible, then in the absence of transportation costs and other distortions, purchasing power parity (PPP) holds, at least up to a disturbance:

$$(p-p^*)_t = e_t + \nu_t \qquad (2^F)$$

where: e denotes the domestic price of a unit of foreign exchange; and ν is a stationary disturbance. (Below, we substitute a model of sticky prices in place of our PPP assumption.) Substituting this equation into (1'), it is trivial to solve for the exchange rate:

$$e_t = (m-m^*)_t - \beta(y-y^*)_t + \alpha(i-i^*)_t - (\varepsilon-\varepsilon^*)_t - \nu_t$$

=>

$$e_t - \alpha(i-i^*)_t = (m-m^*)_t - \beta(y-y^*)_t - (\varepsilon-\varepsilon^*)_t - \nu_t \qquad (3)$$

In the flexible-price model, a standard way to measure "fundamentals" is the "traditional fundamental" (TF), defined by:

$$TF^F{}_t \equiv (m-m^*)_t - \beta(y-y^*)_t, \qquad (4)$$

implicitly assuming that the importance of disturbances to purchasing power parity is negligible. We will also examine a variant of (4), augmented to include a term for money demand disturbances:

$$ATF^F{}_t \equiv (m-m^*)_t - \beta(y-y^*)_t - (\varepsilon-\varepsilon^*)_t. \qquad (4^A)$$

Neither β nor $(\varepsilon-\varepsilon^*)$ is known in reality, although this will not turn out to be very important for our empirical work.

ATF and TF differ in a number of respects. In our empirical work, we parameterize TF explicitly, but measure ATF without an explicit money demand model. Thus one advantage of using ATF rather than TF is that mis-specification of TF will not affect our measured ATF. Another reason to prefer ATF to TF is that it is closer to the latent "fundamental" variable.

Both TF^F and ATF^F differ from the right-hand side of (3) by only the unobservable ν; the PPP assumption implies that this measurement error should be small.

By way of contrast, our "virtual fundamental" (VF) is the left-hand side of (3):

$$VF_t \equiv e_t - \alpha(i-i^*)_t. \qquad (4')$$

The key α parameter is unknown, but our results will prove to be robust across a wide range of interesting and plausible values.1/

Virtual fundamentals, unlike traditional fundamentals, are always tightly related to the exchange rate *within the sample* for reasonable choices of α. Virtual and traditional fundamentals are merely alternative ways of measuring the same latent variable. Both are model-based, use raw economic data, and rely solely on the structural equation (3).

In the absence of substantive measurement error, virtual and traditional fundamentals should behave similarly if the monetary model with flexible prices describes reality "well" (i.e., v_t is relatively unimportant in the sense of having small unconditional and conditional variance). Much of the analysis that follows hinges on comparing the time-series characteristics of VF, TF and ATF (the latter two differ only by (ε-ε*)). Our chosen metric is conditional volatility, which we choose because: a) it is intrinsically interesting; b) it has proven to be difficult to explain with current exchange rate models; c) it allows us to avoid non-stationarity issues; and d) it seems to vary in an interesting and systematic (regime-specific) way.

1/ We have not assumed uncovered interest parity (UIP), i.e., the equation:

$$(i-i^*)_t = E_t(de_t)/dt$$

where $E_t(de_t)/dt$ is the expected rate of change of the exchange rate. UIP is known to work badly in practice for flexible exchange rate regimes. However, if we *were* to add the assumption of UIP, a canonical structural-form single factor exchange rate equation could then be expressed as:

$$e_t - \alpha(i-i^*)_t = e_t - \alpha E_t(de_t)/dt = f_t$$

so that our virtual fundamentals measure f_t, the "fundamental determinant" of the exchange rate.

Ib: Tangential but Brief Notes on the Literature

Our paper differs from the literature in emphasizing *regime-specific* fundamental volatility. Many models of managed exchange rates assume that exchange-rate management does not alter the conditional volatility of fundamentals substantially. For instance, the early target-zone literature (Krugman (1991)) typically assumed that the conditional volatility of fundamentals did not change with the exchange rate regime. Instead, the conditional volatility of the exchange rate was dampened because of a change in the functional (reduced-) form of the relationship linking the exchange rate to fundamentals, often dubbed the "honeymoon effect". Related recent work which emphasizes "leaning against the wind" (Svensson (1992) provides references) still assumes that the conditional volatility of fundamentals does not change much.

As should become obvious below, our use of "fundamental" is not synonymous with "exogenous"; indeed, one of the attributes of the paper is that we do not make strong assumptions about the processes of our forcing variables, including those controlled by the policy authorities. We intend to compare virtual and traditional fundamentals through regimes of both fixed and floating exchange rates, *without claiming that either fundamentals or the regimes themselves are exogenous in any relevant sense*. This is completely reasonable in the context of our monetary model. A set of (ε-ε*) shocks striking the money-market should affect the volatility of money if the exchange rate is fixed completely exogenously; but during a pure float, these shocks drive the exchange rate, since money is exogenous. Thus, the monetary model with flexible prices implies that the conditional volatility of both virtual and traditional fundamentals should be substantially higher during regimes of floating exchange rates than during fixed-rate regimes.

The typical exchange-rate model in the literature consists of: a set of structural equations; a set of equilibrium conditions involving the structural equations; a set of relations for the forcing processes; and an expectations assumption, all of which lead to a reduced-form relation between the exchange rate and a set of variables deemed to be fundamental to the exchange rate. The best known theoretical papers concerning exchange-rate volatility, Dornbusch (1976) and Krugman (1991), direct attention to the shape of the reduced-form relation under regimes of floating and fixed exchange rates respectively. For instance, the Dornbusch "overshooting" result showed how the reduced-form relation can result in conditional exchange rate volatility that is a multiple of the conditional volatility of monetary variables. Krugman's work, which was directed toward an exchange rate floating inside an explicit "target zone", showed how the reduced-form relation can result in conditional exchange rate volatility that is a fraction of the volatility of the relevant market fundamentals. Empirical work directed toward studying reduced-forms, e.g., Meese and Rogoff (1988) and Flood et. al. (1991) has been almost uniformly unsupportive of the theory. In contrast, our derivation of virtual and traditional fundamentals did not rely on *reduced-form* equations; nor will our empirical work rely on reduced-form estimates. This seems both novel and worthwhile, since our empirical work will not be plagued by the very serious problems of either unknown expectations or unstable and poorly identified processes for forcing variables.

It is well known that models of exchange rates work poorly in *floating* exchange rate regimes (e.g., Meese (1990), Meese and Rogoff (1988); less is known about *fixed* exchange rate regimes). This leads most economists to conclude that there is an important variable (or set of variables) omitted from standard models.1/ The contribution of this paper consists in pointing out a striking characteristic of the omitted (set of) variable(s), namely that it has regime-specific conditional volatility, and does not appear in traditional measurements of macroeconomic fundamentals (including deviations from money market equilibrium). Succinctly,

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1/ E.g., Meese (1990, p 132) states: "It remains an enigma why the current exchange rate regime has engendered a time-series data base where macroeconomic variables and exchange rates appear to be independent of one another. One possible explanation is that economists have not yet discovered the appropriate set of fundamentals ..."

macroeconomic models not only cannot explain flexible exchange rates, they cannot explain the difference between fixed and flexible exchange rates.

Ic: The Sticky-Price Model

In reality prices look sluggish, and deviations from purchasing power parity (i.e., v_t) are large and persistent. Further, across OECD exchange rate regimes, nominal and real exchange rate volatility are highly correlated (except possibly at very low frequencies). For all these reasons we examine models that do not rely on perfectly flexible prices.

A standard way to allow for price stickiness is to substitute a Phillips-curve equation in place of the assumption of continuous purchasing power implicit in equation (2^F) (e.g., Obstfeld and Rogoff (1984)):

$$p_{t+1}-p_t = \mu(y-y^{LR})_t + g_t + E_t(p_{t+1}-p_t)$$

$$y_t = \theta'(e+p^*-p)_t + \varphi' r_t$$

$$=> \quad p_{t+1}-p_t = \theta(e+p^*-p)_t + \varphi r_t + g_t + E_t(p_{t+1}-p_t) \qquad (2^S)$$

where: y^{LR} is the long-run level of output (ignored for simplicity); g is a well-behaved shock to goods market equilibrium; $r_t \equiv i_t-E_t(p_{t+1}-p_t)$ is the ex ante expected real interest rate; and $\bar{p}$ is defined by:

$$\theta(e+p^*-\bar{p})_t + \varphi r_t + g_t = 0. \qquad (5)$$

Obstfeld and Rogoff (1984) provide a detailed discussion of the latter term.

Equation (5) can be solved for $\bar{p}_t$ and thus $E_t(\bar{p}_{t+1}-\bar{p}_t)$; when these expressions are substituted back into (2^S), one arrives at:

$$p_{t+1}-p_t = \theta(e+p^*-p)_t + \varphi r_t + g_t + E_t(p^*_{t+1}-p^*_t)$$

$$+ E_t(e_{t+1}-e_t) + \theta^{-1}E_t(g_{t+1}-g_t) + \varphi/\theta E_t(r_{t+1}-r_t). \qquad (2^{S'})$$

Solving this for the exchange rate by substituting into (1'), one can derive:

$$e_t - \alpha(i-i^*)_t = (m-m^*)_t - \beta(y-y^*)_t - (\varepsilon-\varepsilon^*)_t$$
$$- \theta^{-1}E_t[(e_{t+1}-e_t)+(p^*_{t+1}-p^*_t)] + \theta^{-1}(p_{t+1}-p_t) \quad (6)$$
$$- \theta^{-1}g_t - \theta^{-2}E_t(g_{t+1}-g_t) - \varphi/\theta r_t - \varphi/\theta^2 E_t(r_{t+1}-r_t)$$

The analogues to (4) and (4^A) for the sticky-price model are derived by setting the goods-market shocks g to zero, and are therefore:

$$TF^S_t \equiv (m-m^*)_t - \beta(y-y^*)_t - \varphi/\theta r_t - \varphi/\theta^2 E_t(r_{t+1}-r_t) \quad (7)$$
$$- \theta^{-1}E_t[(e_{t+1}-e_t)+(p^*_{t+1}-p^*_t)] + \theta^{-1}(p_{t+1}-p_t)$$
$$= TF^F_t - \varphi/\theta r_t - \varphi/\theta^2 E_t(r_{t+1}-r_t) - \theta^{-1}E_t[(e_{t+1}-e_t)+(p^*_{t+1}-p^*_t)] + \theta^{-1}(p_{t+1}-p_t)$$

and

$$ATF^S_t \equiv (m-m^*)_t - \beta(y-y^*)_t - (\varepsilon-\varepsilon^*)_t - \varphi/\theta r_t - \varphi/\theta^2 E_t(r_{t+1}-r_t) \quad (7^A)$$
$$- \theta^{-1}E_t[(e_{t+1}-e_t)+(p^*_{t+1}-p^*_t)] + \theta^{-1}(p_{t+1}-p_t)$$
$$= ATF^F_t - \varphi/\theta r_t - \varphi/\theta^2 E_t(r_{t+1}-r_t) - \theta^{-1}E_t[(e_{t+1}-e_t)+(p^*_{t+1}-p^*_t)] + \theta^{-1}(p_{t+1}-p_t).$$

If the sticky-price monetary model provides an accurate description of the data (so that the goods-market shock g_t is relatively unimportant), then sticky-price traditional and virtual fundamentals should have similar properties.

II: The Data

IIa: Discussion of the Raw Data

Our empirical work focuses on bilateral American dollar exchange rates from 1960 through 1991 inclusive. We choose this sample because we are interested in comparing exchange rates and their fundamental determinants during regimes of both fixed and floating rates. The Bretton Woods regime of the 1960s is a good example of a fixed exchange rate regime. The exchange rate bands were narrow (±1%, compared with e.g., the ±2.25% of the narrow band of the Exchange Rate Mechanism in the European Monetary System). The Bretton Woods system was a regime of universally pegged exchange rates, with a clear commitment to intervention by the associated central banks (the EMS is a system of exchange rates which are pegged vis-a-vis each other but float jointly relative to other major currencies). One disadvantage of the Bretton Woods era is that Euro-market interest rate data (which are unaffected by political risk) are unavailable for much of the sample. As we discuss below, this will not turn out to be a very serious problem, since none of our results depend on UIP (certainly none depend on UIP holding *exactly*); domestic interest rates are preferable in any case, since they are the relevant opportunity cost of holding money.

Since much of our interest is on conditional volatility of both exchange rates and macroeconomic fundamentals, we choose to work at the monthly frequency. A coarser frequency (e.g., quarterly) would enable us to use national accounts data, but limit the number of observations severely; a finer frequency would preclude use of standard macroeconomic fundamentals such as money and prices. This issue is discussed further below.

We use industrial production indices for our measure of output. We also use narrow (M1) money indices, the consumer price index for prices, and three-month treasury bill returns as interest rates. Our data are transformed by natural logarithms unless otherwise noted (interest rates are usually annualized and always measured as nominal rates divided by 100 so that e.g., an interest rate of 8% is used as .08). The data is taken from the IMF's *International Financial Statistics* and has been checked and corrected for e.g., transcription and rebasing errors. The United States is always considered to be the domestic country so that our exchange rates are measured as the price (in American dollars) of one unit of foreign exchange (e.g., \$2.80/£). We consider eight industrial countries (above and beyond the United States): the United Kingdom; Canada; France; Germany; Holland; Italy; Japan; and Sweden.

Time-series graphs of our raw data are presented in figures 1-5. The exchange rate data are graphed with the ±1% bands during the Bretton Woods regimes that we consider. Tick marks on the abscissa denote the end of the Bretton Woods era (and the beginning of the relevant Bretton Woods regime for Canada, Germany, and Holland, countries which adjusted their pegs early in the 1960s). The actual exchange rate pegs and explicitly declared bands are tabulated in Table I. Interest rate differentials are the difference between annualized American and foreign rates; prices, money and output are portrayed as the ratio of the (natural logarithms of the) American to the foreign variable. Throughout our empirical work, the scales in our graphics are country-specific; comparisons should be done across exchange rate regimes for a given country, rather than between countries.

We note that the nominal exchange rates are obviously quite stable during the Bretton Woods era, but quite volatile during the period which followed. (This well-known characteristic is also true of real exchange rates (Stockman (1983))). However, this dramatic increase in volatility does not characterize such traditional fundamental determinants of exchange rates as money and output.1/ Unless the link between fundamentals and exchange rates varies dramatically across regimes, this constitutes *prima facie* evidence that variables

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1/ The fact that output volatility does not vary substantially by exchange rate regime is consistent with, and first noted by Baxter and Stockman (1989). Baxter and Stockman are interested in a question complementary to ours. They ask: "How does the choice of exchange rate system affect macroeconomic fluctuations?"; whereas our focus is on "What can be learned about exchange rate determination from cross-regime volatility comparisons?".

such as money and output are *not* in fact important determinants of exchange rate volatility, at least for our sample. In some sense, the rest of the empirical work in this project merely extends this result.

IIb: Some Naive Evidence on Volatility Tradeoffs

Frenkel and Mussa (1980, 379) state:

> ... while as a technical matter, government policy can reduce exchange-rate fluctuations, even to the extent of pegging an exchange rate, it may not be assumed that such policies will automatically eliminate the disturbances that are presently reflected in the turbulence of exchange rates. Such policies may only transfer the effect of disturbances from the foreign exchange market to somewhere else in the economic system. There is no presumption that transferring disturbances will reduce their overall impact and lower their social cost. Indeed, since the foreign exchange market is a market in which risk can easily be bought and sold, it may be sensible to concentrate disturbances in this market, rather than transfer them to other markets, such as labor markets, where they cannot be dealt with in as efficient a manner.

In this sub-section, we attempt to get a handle on this issue in a naive way. By "naive" we really mean "bivariate" or "model-free"; thus this sub-section is really a tangent to the main thrust of the paper.

For each of the nine countries in our sample, we obtained the monthly IFS measure of the nominal effective exchange rate. These data (which are discussed in detail in *International Financial Statistics*) were obtained from 1975 through 1990. After dividing our sample into eight two-year samples, we computed the sample standard deviation of the first-difference of the natural logarithm of the effective exchange rate for each of the eight periods and nine countries. We then computed the analogues for domestic output, interest rates, and money. We are then left with a panel of 72 observations (nine countries by eight sample periods) of volatility. Scatter plots are provided in figures 6-8, which respectively graph exchange rate volatility against the volatility of output, interest rates, and money. In these graphs, observations are marked by country (America, Britain, Canada, France, Germany, Holland, Italy, Japan, Sweden).

The graphs indicate that there is no substantial tradeoff between exchange rate volatility and the volatility of (domestic) interest rates. Some evidence of a tradeoff between exchange rate volatility and both output and money volatility is apparent in the graphs, mostly because of a few outliers in the lower right part of the graphs. Significantly negative simple correlations between $\sigma(e)$ and both $\sigma(y)$ and $\sigma(m)$ can be confirmed statistically at traditional confidence levels. However, the finding of a negative correlation between $\sigma(e)$ and $\sigma(m)$ vanish when the outliers are excluded; the only robust result is the tradeoff between exchange rate and output volatility.1/

It may be interesting to note parenthetically that there is also no clear sign of a tradeoff between exchange-rate and stock-return volatility. Figure 9 is a scatter plot of exchange-rate volatility and stock-market volatility computed in an analogous manner (that is, the standard deviation of the first difference of the log of the IFS aggregate stock market index, computed for samples of two years of monthly data). Our data also do not reveal any signs of a simple tradeoff between exchange rate volatility and either the level or volatility of inflation.

To summarize, with the exception of a negative, statistically significant correlation between nominal effective exchange rate volatility and output volatility, there do not appear to be simple tradeoffs between exchange rate volatility and the volatility of standard macroeconomic variables. The absence of a correlation between exchange rate and money volatility is especially striking in the context of monetary models. Of course, the monetary model does not imply a strict tradeoff between money and exchange rate volatility (the correct

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1/ The R^2 of this relationship is approximately .2. None of these results depend on the absence (or presence) of either country- or time-specific "fixed effects" (or both). Also, there is no significant tradeoff between the volatility of the exchange rate and the *levels* of the macroeconomic variables considered.

tradeoffs are embodied in equations (3) and (6) presented above), so this evidence should be taken as suggestive, rather than definitive.

IIc: More on Reserves

Monetary models of the exchange rate imply that stabilization of the exchange rate is achieved at the cost of a more volatile money supply. The tradeoff between exchange rate volatility and money supply volatility *should* be more apparent for narrower concepts of money such as the monetary base, or indeed international reserves (e.g., Stockman (1983)). The correlation between exchange-rate and money volatility was not well determined from the evidence above, given the important outliers. It is therefore interesting to see whether a clearer picture can be obtained from an examination of more narrow monetary aggregates.

Figure 10 is a scatter plot of nominal effective exchange-rate volatility against the volatility of total reserves (IFS line 1), computed in the same fashion as in the sub-section above. The hypothesis that there is no correlation between exchange-rate and reserve volatility can only be rejected at the 40% confidence level. Figures 11 and 12 show similar results for two more narrow reserve concepts, total non-gold reserves (IFS line 1l.d) and reserves of foreign exchange only (line 1d.d).

It may seem striking that there is no apparent tradeoff between exchange-rate volatility and the behavior of international reserves. Some further detail on this issue can be found in Figure 13, which shows time-series plots of the percentage change in total reserves for each of the nine countries. In figure 13, the plots are broken into two distinct segments: the period during the Bretton Woods regime when the country was obligated to intervene to maintain the currency within tight bands; and the period after June 1973. Of course, the period after 1973 does not correspond to a generalized float, since many countries managed their floats either implicitly (as is true in e.g., the Canadian case) or explicitly (as is true of the ERM countries). There are sometimes major differences in the time-series characteristics of reserves between the

Bretton Woods era and the post-1973 era. However, there is little evidence of a general *decrease* in reserve volatility as countries moved from the Bretton Woods regime of adjustable pegs to the post-1973 era. Indeed the volatility of reserves for Canada, France, Germany, Italy, and Sweden seems to be systematically higher after the demise of Bretton Woods.1/,2/

III: Empirical Results

IIIa: Virtual Fundamentals

The construction of virtual fundamentals requires only one piece of non-observable information, i.e., α.

The literature indicates that α, the interest semi-elasticity of money demand (with units years, since we use annualized interest rates), is likely to be a small number (e.g., the discussion in Flood et. al. (1991)). We believe that a value of α=.1 is reasonable, and that α=1 is excessively high. While we believe that α=.5 is implausibly high, we pick it as our default value so as to make our case under adverse conditions (lower, more realistic, values of α will typically strengthen our arguments). However, it turns out that our results do not really depend on α very much; even α values of substantially greater than unity deliver our main point.3/

1/ This result is not true of narrower concepts of reserves. For both total non-gold and foreign exchange reserves, the U.K., France, Germany, Holland and the USA experienced decreases in reserve volatility.

2/ European monetary arrangements (beginning with the Snake and continuing with the EMS) may explain some of this increase in reserve volatility for France, Germany and Italy. However, this is by no means clear, given the exchange controls, loose bands, and poor credibility of European exchange arrangements, especially in the early 1980s.

3/ We have attempted to estimate α directly. We derive our estimating equation by using UIP and taking first-differences:

$$\Delta e_t = \alpha\Delta(i-i^*)_t + \eta_t$$

where the fundamental process is given by $f_t = f_{t-1} + \eta_t$ and η is a well behaved disturbance term (white noise if f_t is a random walk).

To estimate this equation, we use IV, using 3 lags of both Δe and Δ(i-i*) as instrumental variables. The results are poor in the sense that is usually imprecisely estimated, always with a *negative* point estimate. (While we doubt that our instrumental variables are highly correlated with the regressor, we note that OLS delivers similar results, although positive but insignificant estimates are obtained for the U.K. and Canada).

We have also tried to estimate α directly through various money demand equations with

Figure 14 is a series of time series plots of the first-difference in virtual fundamentals for our eight different exchange rates, using a value of α=.5. (An analogue for our preferred value α=.1 is included in the appendix, and leads to similar conclusions.) If fundamentals follow a random walk, then the first-difference is also the innovation.1/ As usual, in our time series plots we graph the variables for both the Bretton Woods regime when the exchange rate was pegged, and the period of more floating rates which began after June 1973. The graphs show a striking phenomenon, which is central to this paper, namely that *the volatility of virtual fundamentals is much higher in regimes of floating rates than during regimes of fixed rates.* This result does not depend on the exact choice of α.

IIIb: Traditional Fundamentals for the Flexible-Price Monetary Model

A β value is required to measure traditional fundamentals. This parameter corresponds to the income elasticity of money demand; we choose β=1 as a reasonable benchmark (Goldfeld and Sichel (1990) provide a relevant survey).

For simple money demand functions, all that is required for ATF construction is α. This can be seen by considering OLS on the differenced money demand function:

$$(m-m^*)_t - (p-p^*)_t = \beta(y-y^*)_t - \alpha(i-i^*)_t + (\varepsilon-\varepsilon^*)_t \qquad (8)$$

$$\Rightarrow \quad (\varepsilon-\varepsilon^*)_t \equiv (m-m^*)_t - (p-p^*)_t - (y-y^*)_t + (i-i^*)_t$$

$$\Rightarrow \quad ATF^F{}_t = (p-p^*)_t - (i-i^*)_t. \qquad (4^{A\prime})$$

It might be objected that a simple static (differential) money demand function such as (8) is likely to fit the data extremely poorly. While this point is surely true, our interest in (8) is peripheral, since we are only interested in the *conditional innovations of the traditional*

(..continued)
similarly poor results; α typically turns out to be small and insignificant, often negative.

1/ The hypothesis that virtual fundamentals (and, parenthetically, traditional fundamentals) contain a unit-root cannot typically be rejected at conventional significance levels. However a first-order autoregressive coefficient (typically with a coefficient of around .4) is often significant, so that the hypothesis of a pure random walk can frequently be rejected.

fundamentals. That is, including extra dynamics in (8) will result in the presence of extra lagged terms in (4^{A}'), but unchanged ATF innovation volatility.

Time series plots of the first-differences of TF generated with β=1 are presented in figure 15; comparable plots for ATF generated with α=.5 are presented in figure 16. There are some country-specific differences in TF volatility between regimes of fixed and floating rates. However, these are relatively small and subtle. Again, the appendix contains analogues for different parameter values. All are consistent with the conclusion that *in contrast with virtual fundamentals, the volatility of traditional fundamentals does not vary dramatically across exchange rate regimes*.

IIIc: Comparing Alternative Fundamentals for the Flexible-Price Monetary Model

We now compare virtual and traditional fundamentals for the flexible-price model. This can be done directly by comparing figure 14 (i.e., ΔVF) with figures 15 and 16 (ΔTF and ΔATF respectively). Clearly, the conditional volatility of VF rises when one compares the Bretton Woods regime with the post-Bretton Woods data, sometimes by an order of magnitude. This is true for all reasonable values of alpha, and all currencies. Equally clearly, there is no comparably large difference in TF or ATF volatility across exchange rate regime, at least for the tabulated currencies and parameter values.

Although we find the plots in figures 14-16 convincing, the evidence is ocular rather than econometric. Nevertheless, it is remarkably easy to produce the statistical analogues. Suppose that ΔTF_t ($\equiv TF_t - TF_{t-1}$), ΔATF_t, and ΔVF_t are normally distributed. Then the ratio of the regime-specific sample variances, e.g., $(\Delta TF_{Float})/(\Delta TF_{Fix})$, suitably scaled by a factor to correct for degrees of freedom, is distributed as F under the null hypothesis of equal variances across exchange rate regimes.1/

1/ We checked for normality by looking for excess skewness and kurtosis. For some currencies and some alpha values, there are clear signs of non-normality which lead one to reject the hypothesis of normality at conventional confidence levels. We conclude that the hypothesis

Table II contains estimates of the ratio of the *standard deviation* of the first-difference of fundamentals during the post-Bretton Woods era to the standard deviation of the first-differences of fundamentals during the Bretton Woods regime. (We tabulate ratios of standard deviations (rather than the corresponding F-statistics) in order to highlight situations where fundamental volatility was actually lower in the post-1973 regime than in the Bretton Woods regime.) Different lines correspond to different concepts of fundamentals and different parameter values. The relevant F statistics can be obtained by simply squaring the tabulated statistic (or $|x-1|+1$ if $x<1$ where x is the statistic). Under the null hypothesis of equal volatility, the appropriate number of degrees of freedom in the numerator is approximately 220, and the number of degrees of freedom in the denominator is approximately T, tabulated in Table I. As the .05 and .01 critical values for F(200,100) are 1.32 and 1.48 respectively, the statistics tabulated in Table II are inconsistent with the null hypothesis at the .05 (.01) confidence level if they surpass approximately 1.15 (1.22). Starred statistics denote combinations where the null hypothesis of no substantial increase in volatility *cannot* be rejected at different confidence levels. The null hypothesis of no increase in volatility is wholly at odds with all the VF series; it fares much better (but is still frequently rejected, especially for the sticky-price model) for traditional fundamentals.1/

It is striking that the traditional fundamentals often do not show a marked secular increase in volatility across exchange rate regimes; indeed, there are a number of instances of lower traditional fundamental volatility in the post-Bretton Woods regime. Nevertheless, we are not

(..continued)
of normality is not literally true, but does not seem to be grossly at odds with the data. Thus we try not to take the exact confidence levels of our tests too literally; it turns out that there is no reason for us to do so.

1/ The end of an exchange rate peg is often associated with a large change in e and VF. It is therefore interesting to note in passing that the dramatic increase in VF volatility when a fixed rate begins to float also characterizes VF time series when the fixed-rate regime is extended through the month(s) at the end (and beginning) of the Bretton Woods peg. See Rose (1995) for more analysis.

really interested in the null hypothesis that fundamental volatility is equal across regimes. Rather, we are interested in the question: do virtual and traditional fundamentals have similar time-series characteristics? In particular, do the TF and ATF series mimic the increase in volatility experienced by all the VF series? The answer is clearly negative; the hypothesis that the ratio of post-Bretton Woods to Bretton Woods volatility is equal for the virtual and traditional series can be rejected at greater than the .99 level for essentially all currencies and parameter values considered.

Scatter plots of ATF against VF for α=.5 are contained in Figure 17 (the TF:VF analogue is similar, and is contained in the working paper version). In the graph, non-parametric data smoothers are drawn to "connect the dots"; Bretton Woods observations are highlighted by diamond marks. It is clear that virtual and traditional fundamentals are only loosely associated. This finding can be corroborated with standard regression techniques, which show that virtual and traditional fundamentals are typically very imperfectly correlated (the R^2 in a regression of virtual on traditional fundamentals is typically around .05). Indeed, many of the correlations are negative for the sticky-price model.1/

It may be illuminating to make comparisons across countries for a given period of time, rather than across time for a given country. Since 1979, the volatility of traditional fundamentals of Germany vis-a-vis France, Holland, and Italy has been approximately equal to that of Germany vis-a-vis Japan and the United States. But the volatility of virtual fundamentals for the three European countries (who peg to Germany through the EMS) is only around a

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1/ Since (i-i*) enters both ATF and VF, deviations from UIP cannot explain the different volatility characteristics between the two. Indeed, deviations from UIP which are not regime-specific cannot explain regime-specific volatility patterns. Insofar as there are regime-specific UIP deviations, they are likely to be smaller during the floating rate regime, since capital controls have gradually diminished in importance; however, this makes the jump in VF volatility even more striking. In any case, it is not necessary to assume either perfect capital mobility or UIP to derive our VF and (A)TF measures.

fourth of those of Japan and the United States, who float against the DM.1/

To summarize, there is overwhelming evidence that the volatility of virtual fundamentals for floating currencies is significantly higher than that for fixed countries. However, this is by no means clear for traditional macroeconomic fundamentals; for reasonable parameter values, there is no substantial difference in volatility across exchange rate regimes. Traditional and virtual are positively correlated for reasonably high values of α (e.g., .5), but the relationship is very noisy.

IIId: Traditional Fundamentals for the Sticky-Price Monetary Model

Construction of virtual and traditional fundamentals for the monetary model with flexible prices required only α and β above and beyond raw data. In order to construct traditional fundamentals for the monetary model with sticky prices, we need estimates of θ, φ, $E_t(e_{t+1}-e_t)$, $E_t(p^*_{t+1}-p^*_t)$, r_t, and $E_t(r_{t+1}-r_t)$.

We use the literature to guide us in choosing appropriate θ and φ values. The largest estimate we have found for θ is in Frankel (1979), who uses a variant of (6) with quarterly data and estimates θ to be .19. Papell (1988) also uses quarterly data and estimates θ to be between .02 and .12 for four different countries. Meese and Rogoff (1988) estimate θ to be between .01 and .03, insignificantly different from zero; Mark (1990) finds comparable results. We consider θ=.01 to be quite reasonable, and θ=.1 to be an extreme upper bound at the monthly frequency.2/ As higher values of theta make our case harder to prove, we choose θ=.1 as the default. We also choose φ=.1 as our default, although there is a much smaller empirical literature on φ values (Papell estimates φ to be between .01 and .76, though with large standard errors).

We construct a proxy for $E_t\Delta p^*_{t+1}$ by regressing Δp^*_{t+1} against a "reasonable" information

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1/ Rose (1993) provides more detail.
2/ Direct estimation of θ leads to estimates of around .01, insignificantly different from zero.

set, typically consisting of $\{\Delta p^*_t, \Delta p^*_{t-1}, \Delta q_t, \Delta q_{t-1}, \Delta y^*_t, \Delta y^*_{t-1}\}$, where $q_t \equiv e_t + p^*_t - p_t$ is the real exchange rate. A similar procedure is used to estimate $E_t \Delta e_{t+1}$, adding the interest differential and exchange rate changes to the information set. (We have also used uncovered interest parity to substitute $(i-i^*)_t$ for $E_t(e_{t+1}-e_t)$ with similar, even stronger results). In order to construct a proxy for the real interest rate, we construct a proxy for $E_t(p_{t+1}-p_t)$ by regressing Δp_{t+1} on a comparable domestic information set, and subtracting the fitted value from the nominal interest rate, since $r_t \equiv i_t - E_t(p_{t+1}-p_t)$.1/

Figures 18 and 19 are the time series plots of our benchmark TF and ATF series for the sticky-price model (the working paper version contains analogues for different parameter values, as well as the corresponding scatter plots; results are similar). It is clear that none of our conclusions are changed substantially by modelling prices as sticky rather than perfectly flexible. The reason for this is that, even apart from the size of θ and φ, the volatility of r_t does not vary much across exchange rate regimes. Adding a term with relatively constant volatility to the traditional fundamental reinforces the fact that the volatility of TF (or ATF), unlike that of VF, does not vary much across exchange rate regimes. Indeed, for this reason, we expect that virtually all known macroeconomic exchange rate models will deliver broadly comparable results, since they depend on variables whose volatility does not systematically vary much across exchange rate regimes (Baxter and Stockman (1989) provide some relevant evidence).2/,3/

We note in passing that the volatility of traditional fundamentals is not always roughly constant, since TF volatility rises dramatically during hyper-inflationary periods. For instance,

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1/ With the exception of Holland, the relationships between inflation and the information sets are often tight, with R^2 values ranging up to .5.

2/ The results which have been presented in the paper have been computed with monthly data. As it is well-known that the time-series with which we are concerned can all be empirically modelled as processes with unit-roots, it is plausible to believe that our results will also hold at coarser frequencies. Nevertheless, we temporally aggregated all of our data up to the quarterly frequency and recomputed our test statistics; none of our conclusions were substantially altered.

3/ Further, our evidence shows that any (e.g., microeconomic) factor which operates by affecting money market equilibrium is also at odds with the data.

the volatility of the growth of German prices and money rises by an order of magnitude from 1921 to 1923. Thus, the poor correspondence between VF and TF volatility which characterizes "normal" periods, may disappear during extraordinary episodes such as hyperinflations. We plan to examine this issue further in future research.

IV: A Summary and a Tentative Conclusion

Economists know remarkably little about exchange rates. In this paper, we have tried to exploit a fact that we *do* know: conditional exchange rate volatility is substantially higher in floating rate regimes than it is during regimes of fixed rates. We propose a simple benchmark as a specification test: any plausible empirical model of exchange rates should be able to account for this stylized fact. This indisputable fact has considerable power: for instance, flexible- and sticky-price monetary models cannot account for it. Indeed, as few macroeconomic variables for OECD countries experience dramatic changes in volatility which coincide with exchange rate regimes, we doubt that any exchange rate models based only on macroeconomic fundamentals can pass our simple empirical hurdle, at least during periods of tranquility.

Given that exchange rate volatility frequently seems to change dramatically when the volatility of macroeconomic variables does not, it should not be surprising that we cannot find any strong tradeoff between exchange rate volatility and the volatility of a variety of different macroeconomic variables (e.g., interest rates, relative prices, money, reserves, and stock returns). That is, we can see little empirical evidence that reducing exchange rate volatility compromises the stability of other macroeconomic variables. However, we are unwilling to make policy recommendations in the absence of a fully articulated model which *can* explain exchange rate volatility (let alone sustainable exchange rate *levels*).

We believe that future research should shy away from macroeconomic fundamentals, and concentrate on more microeconomic detail. Krugman and Miller (1993) introduce stop-loss traders into a simple model of the foreign exchange market. A microeconomic focus like this may well provide a future rationalization for the phenomenon of regime-varying VF volatility.

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Table I: Bretton Woods Regimes of Fixed Exchange Rates after 1960

Country	Par Value	Declared Range	T	Dates
UK	\$2.8=£	(2.78,2.82)	94	through 11-18 1967
Canada	C\$1=\$.9275 (+/- 1%)		95	5-2 1962 through 5-31 1970
France	Ffr4.93706=\$	(4.9,4.974)	115	through 8-10 1969
Germany	DM4=\$	(3.97,4.03)	101	3-6 1961 through 9-30 1969
Holland	fl3.62=\$	(3.5295,3.6475)	121	3-7 1961 through 5-9 1971
Italy	Lit625=\$	(620.5,629.5)	139	through 8-15 1971
Japan	¥360=\$	(357.3,362.7)	139	through 8-27 1971
Sweden	Skr5.17321=\$	(5.135,5.2125)	139	through 8-23 1971

Table II: Volatility Ratios of First-Differenced Fundamentals

Country	U.K.	Canada	France	Germ'y	Holland	Italy	Japan	Sweden
Benchmark Parameters ($\alpha=.5$, $\beta=1$, $\theta=\varphi=.1$)								
VF	9.07	3.38	9.31	7.44	8.63	9.74	3.95	5.82
Flexible-Price Model								
TF	1.02**	1.15*	.50**	1.19*	1.70	1.10**	1.06**	1.00**
ATF	1.66	1.60	1.39	1.07**	.88**	1.79	1.28	1.40
Sticky-Price Model								
TF	1.09**	1.27*	.75	1.23*	1.46	1.02**	1.01**	1.10**
ATF	1.22*	1.18**	1.16**	1.04**	1.29	1.42	.97**	1.31
Perturbations								
VF ($\alpha=.1$)	18.37	4.27	18.68	10.68	13.42	15.74	9.45	12.78
VF ($\alpha=1.$)	5.26	2.59	5.44	4.90	6.05	6.33	2.28	3.54
Flexible-Price Model								
TF ($\beta=1.5$)	1.06**	1.16*	2.34	1.11**	1.72	1.08*	1.00**	1.02**
ATF ($\alpha=.1$)	1.47	1.52	1.06**	1.16*	1.99	1.19*	1.14**	1.22
ATF ($\alpha=1.$)	1.89	1.67	1.63	1.30	1.41	2.39	1.36	1.54
Sticky-Price Model								
TF ($\theta=\varphi=.01$)	1.21*	1.20*	1.17**	1.10**	1.16**	1.29	1.01**	1.21*
ATF (")	1.23*	1.18**	1.16**	1.06**	1.16**	1.33	1.01**	1.24*
TF ($\theta=\varphi=.5$)	1.03**	1.21*	.52	1.22*	1.74	1.00**	1.04**	1.10**
ATF (")	1.32	1.21*	1.22*	.98**	1.23*	1.73	.82	1.54
Sticky-Price Model under UIP ($\alpha=.5$, $\beta=1$, $\theta=\varphi=.1$)								
TF	1.71	1.46	1.49	1.51	1.96	1.62	1.78	1.49
ATF	1.88	1.50	2.12	1.41	2.14	2.29	2.10	2.14

Tabulated statistics are ratios of sample standard deviations (of the first-difference of the fundamental) for the post-June 1973 regime to the sample standard deviations for the Bretton Woods regime. Two asterisks indicate that the null hypothesis of equal volatility cannot be rejected at the .05 confidence level; one indicates that the hypothesis can be rejected at the .05 but not the .01 level. Asymptotic 95% (99%) confidence intervals are approximately ±.19 (±.25) around the point estimate.

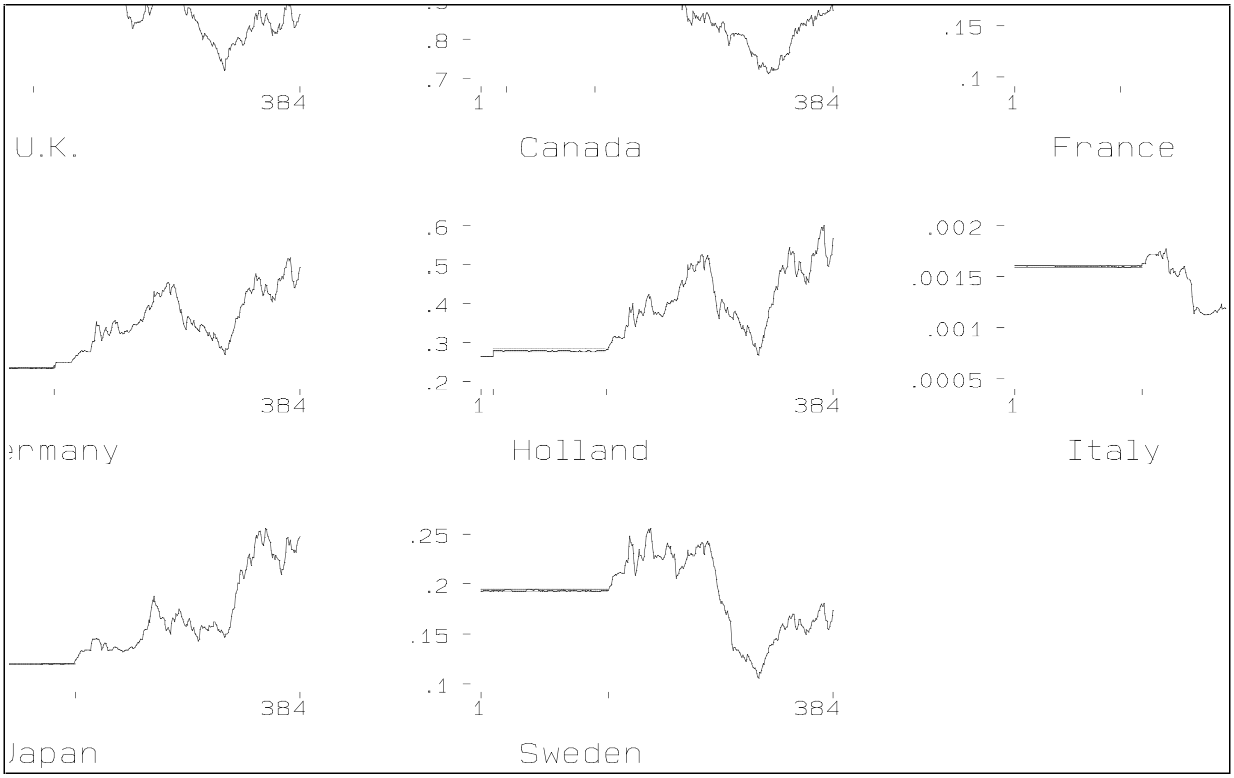

Figure 1: Time series of raw e data

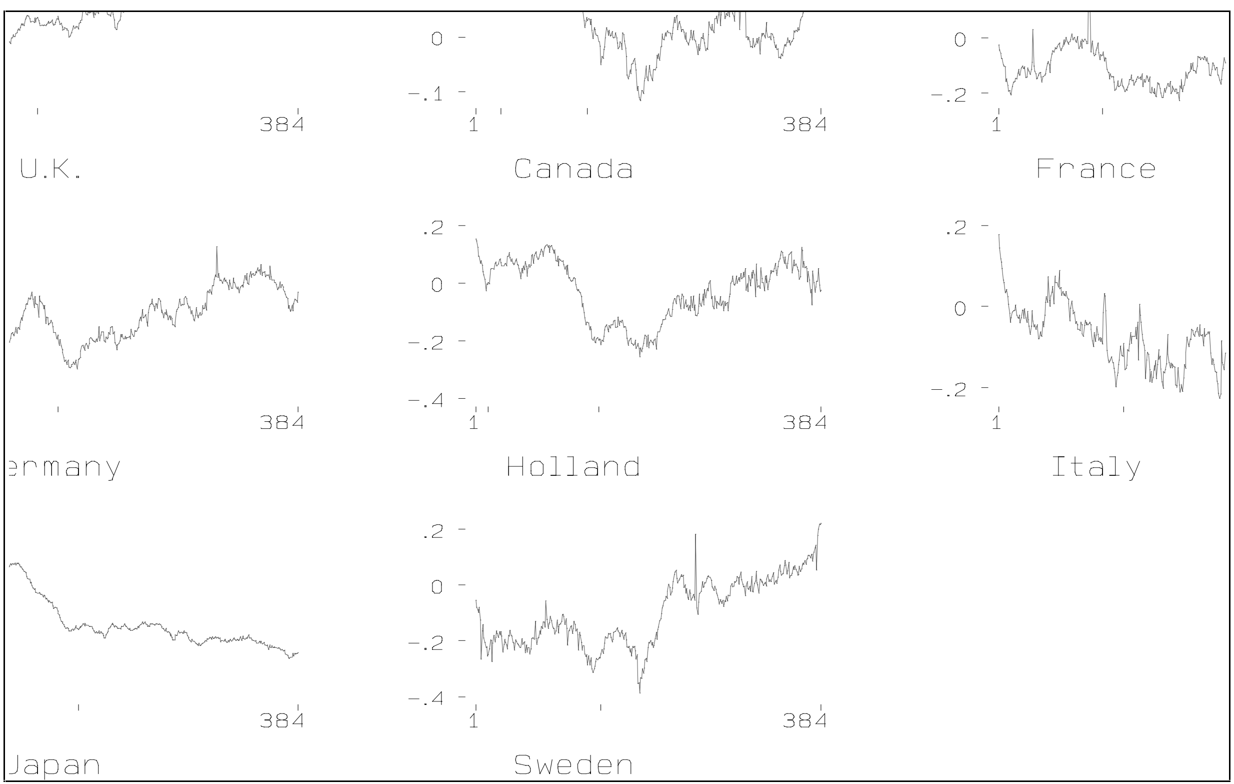

Figure 2: Time series of raw (y-y*) data

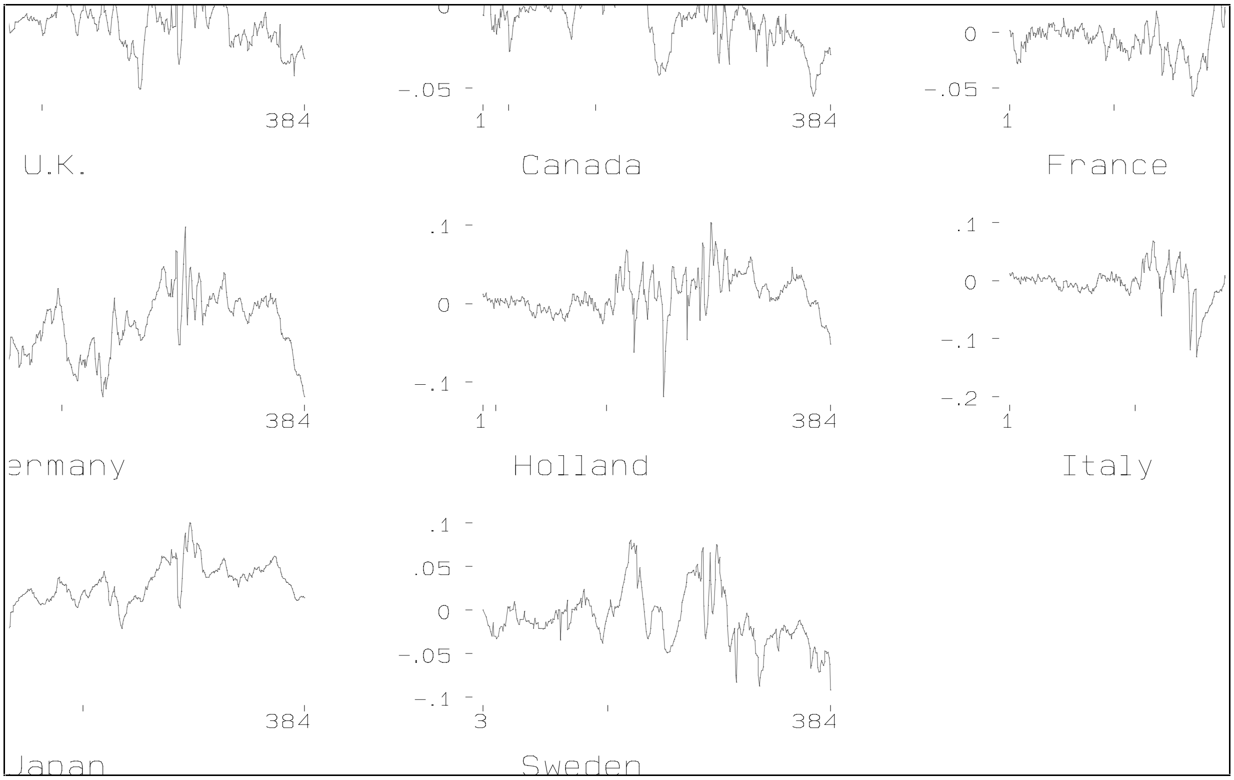

Figure 3: Time series of raw (i-i*) data

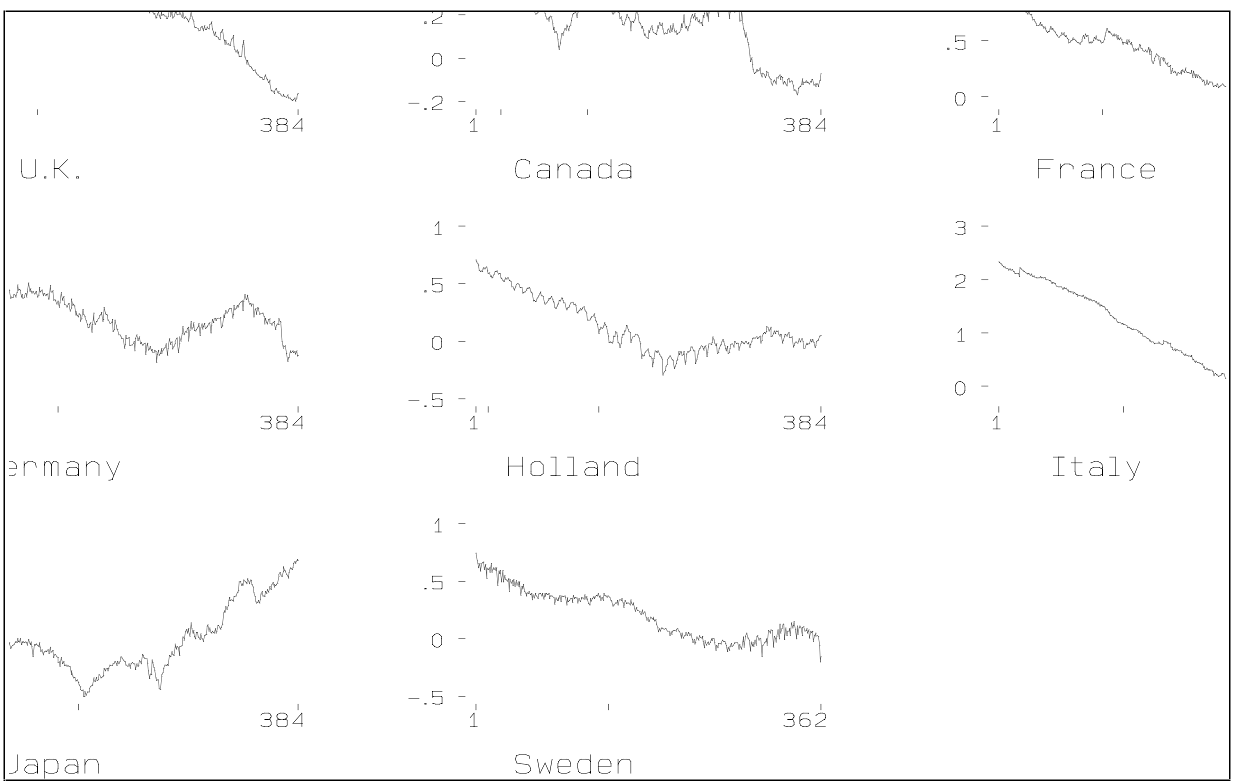

Figure 4: Time series of raw (m-m*) data

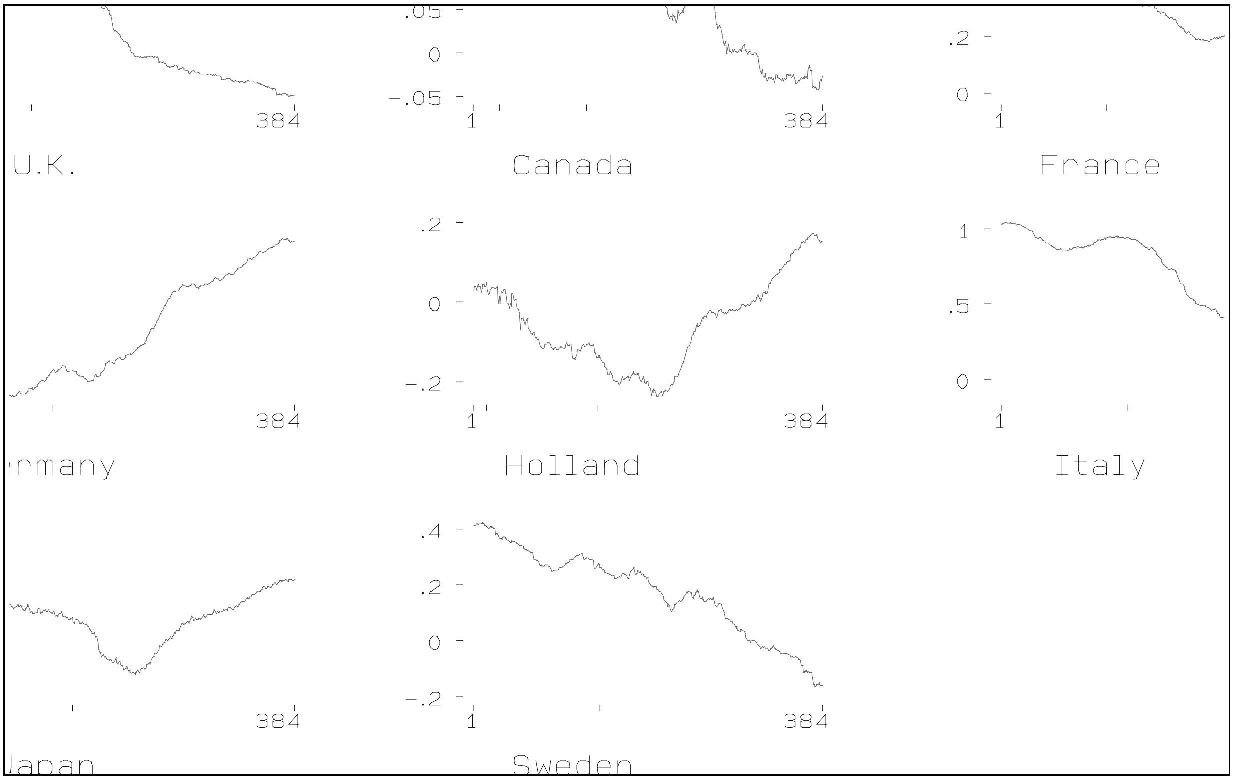

Figure 5: Time series of raw (p-p*) data

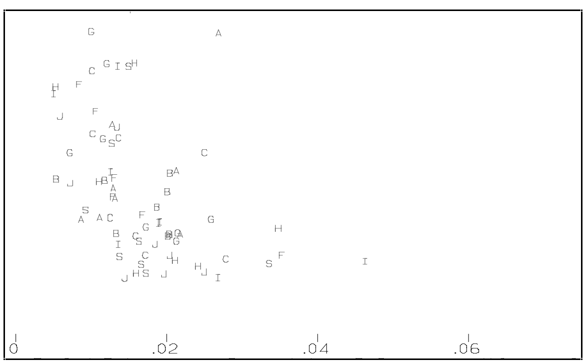

Figure 6: σ(e) against σ(y)

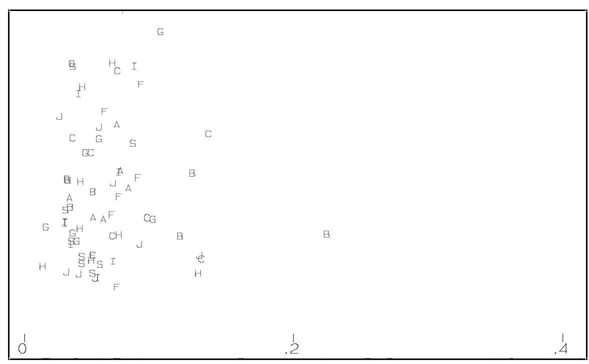

Figure 7: σ(e) against σ(i)

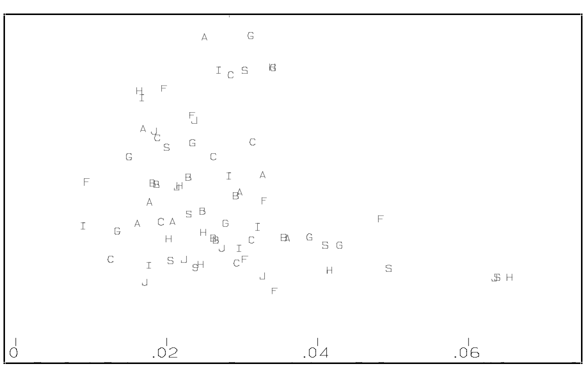

Figure 8: σ(e) against σ(m)

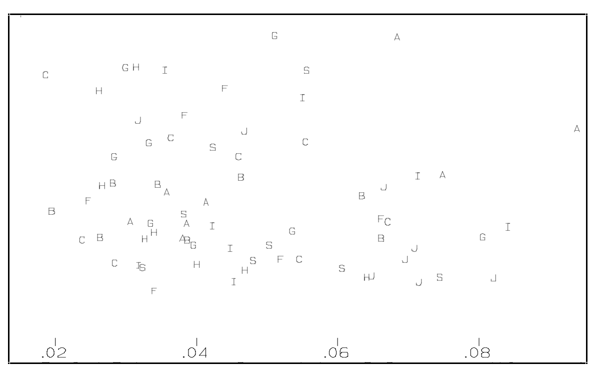

Figure 9: σ(e) against σ(Stck)

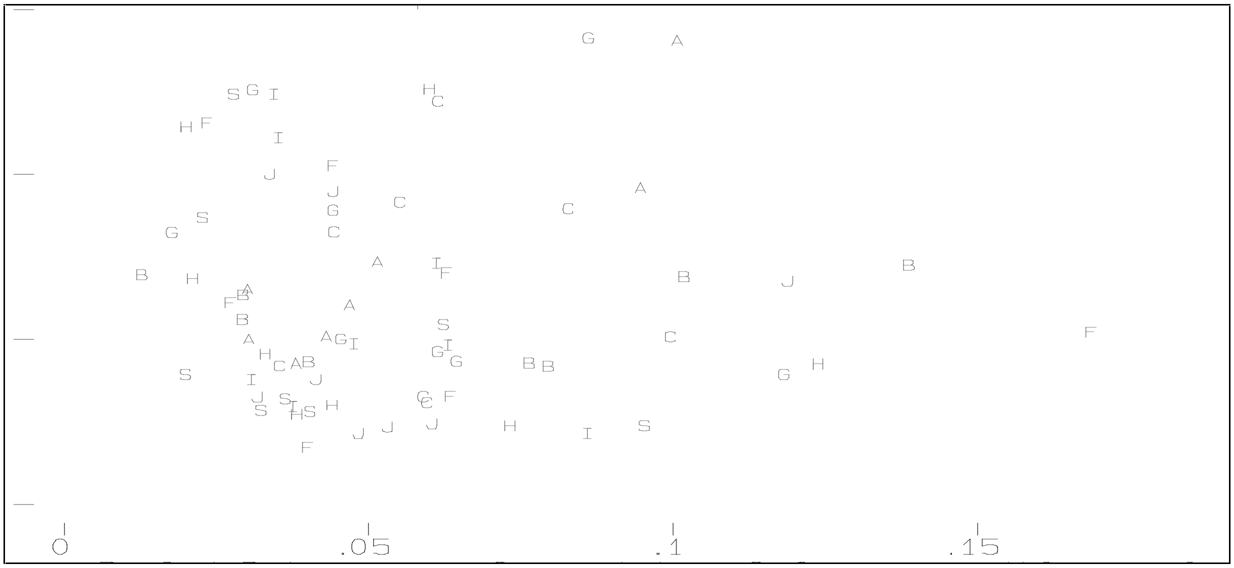

Figure 10: σ(e) against σ(Reserves)

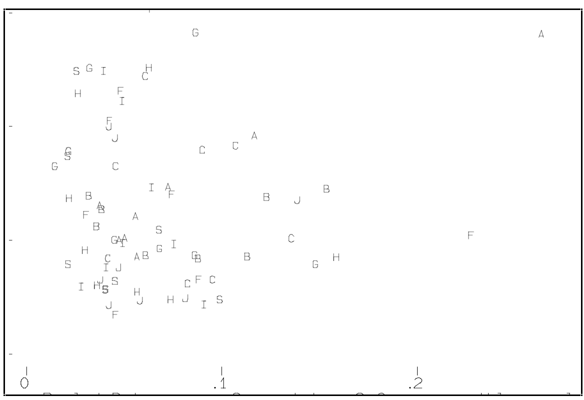

Figure 11: Non-Gold Reserves

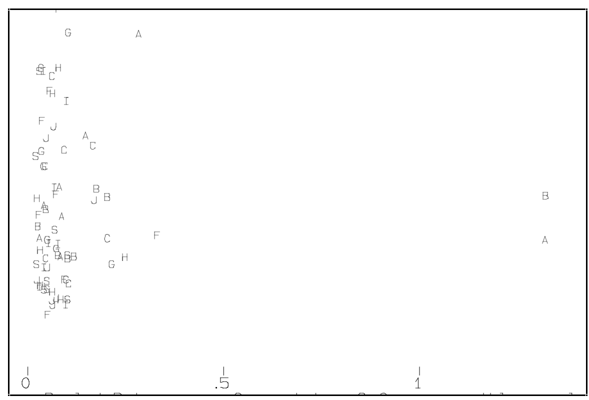

Figure 12: FX Reserves

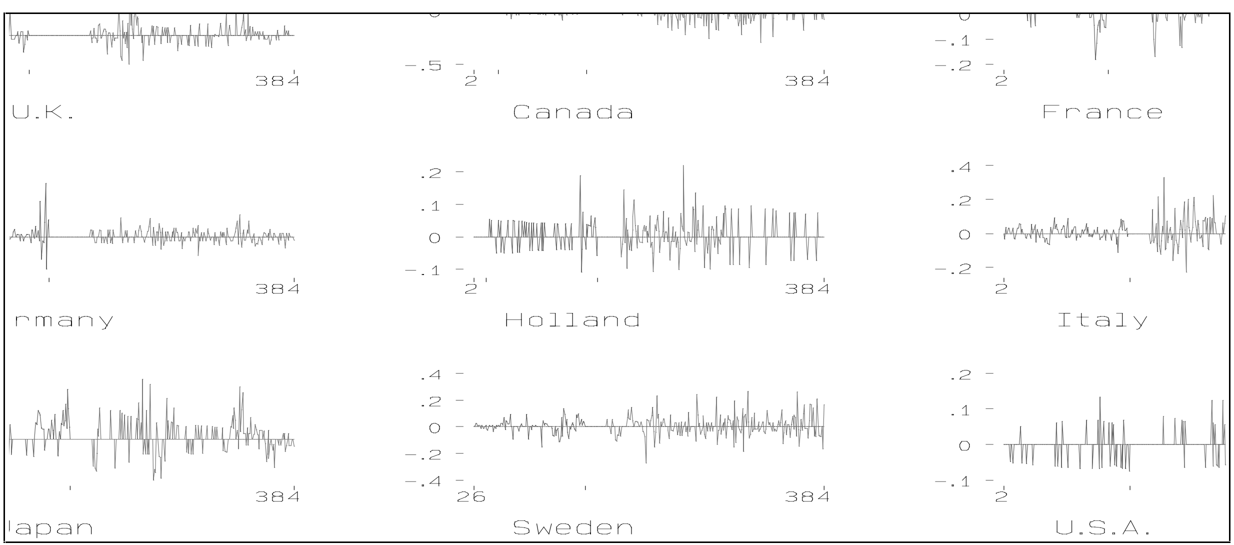

Figure 13: Time series of Reserves during Fixed and Floating Exchange Rate Regimes

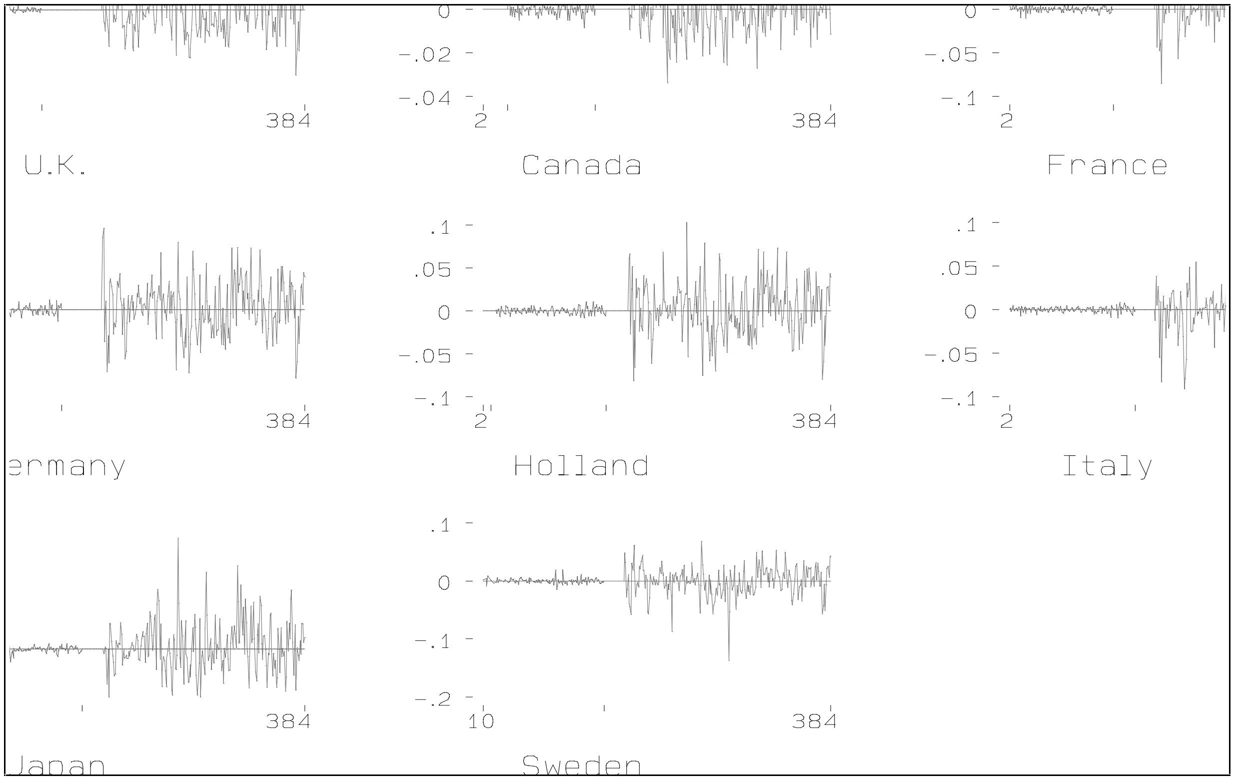

Figure 14: Time series of Benchmark Virtual Fundamentals

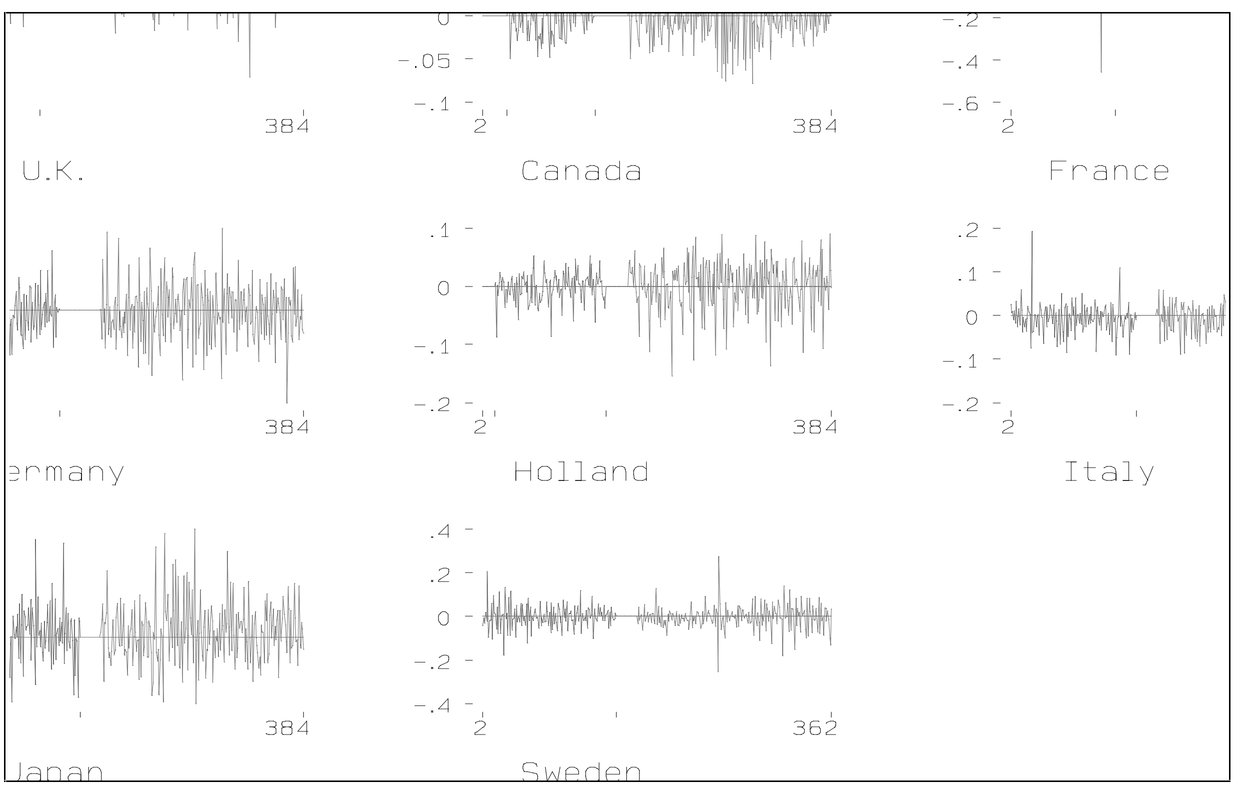

Figure 15: Time series of Traditional Fundamentals, Benchmark Flexible-Price Model

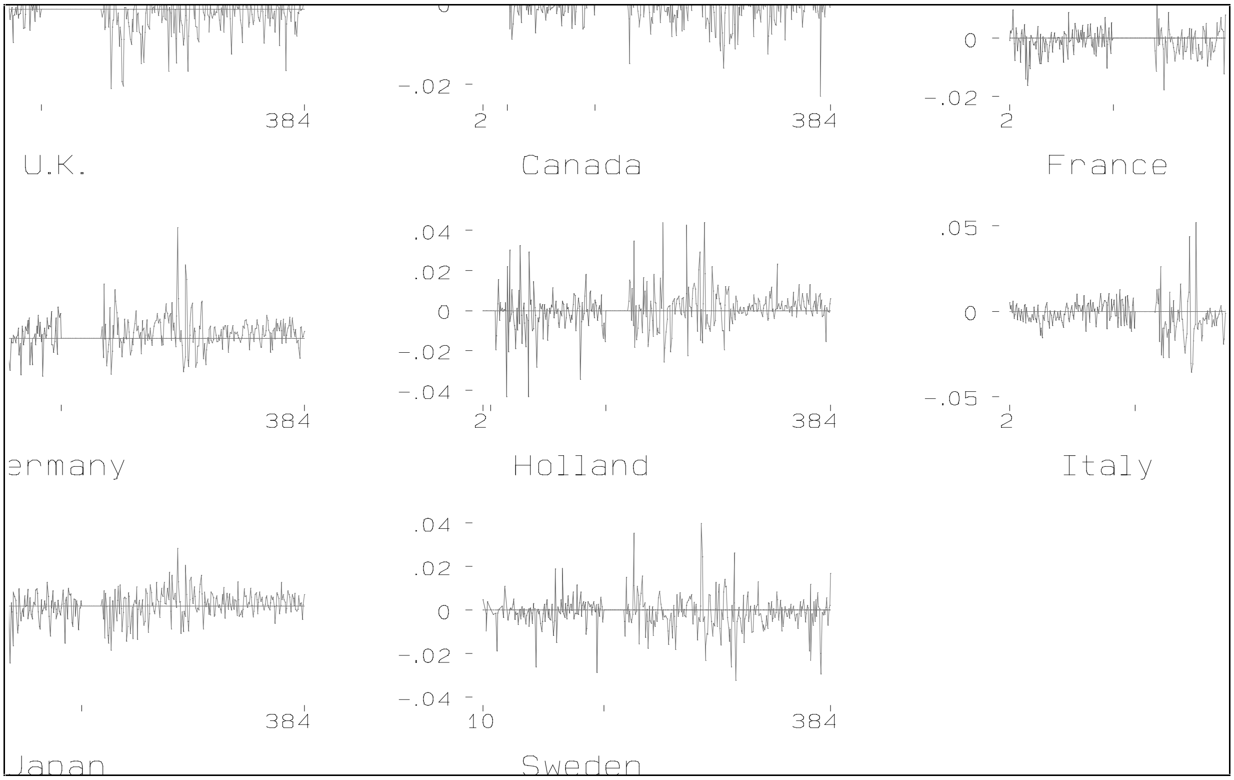

Figure 16: Time series of Augmented Traditional Fundamental, Flexible-Price Model

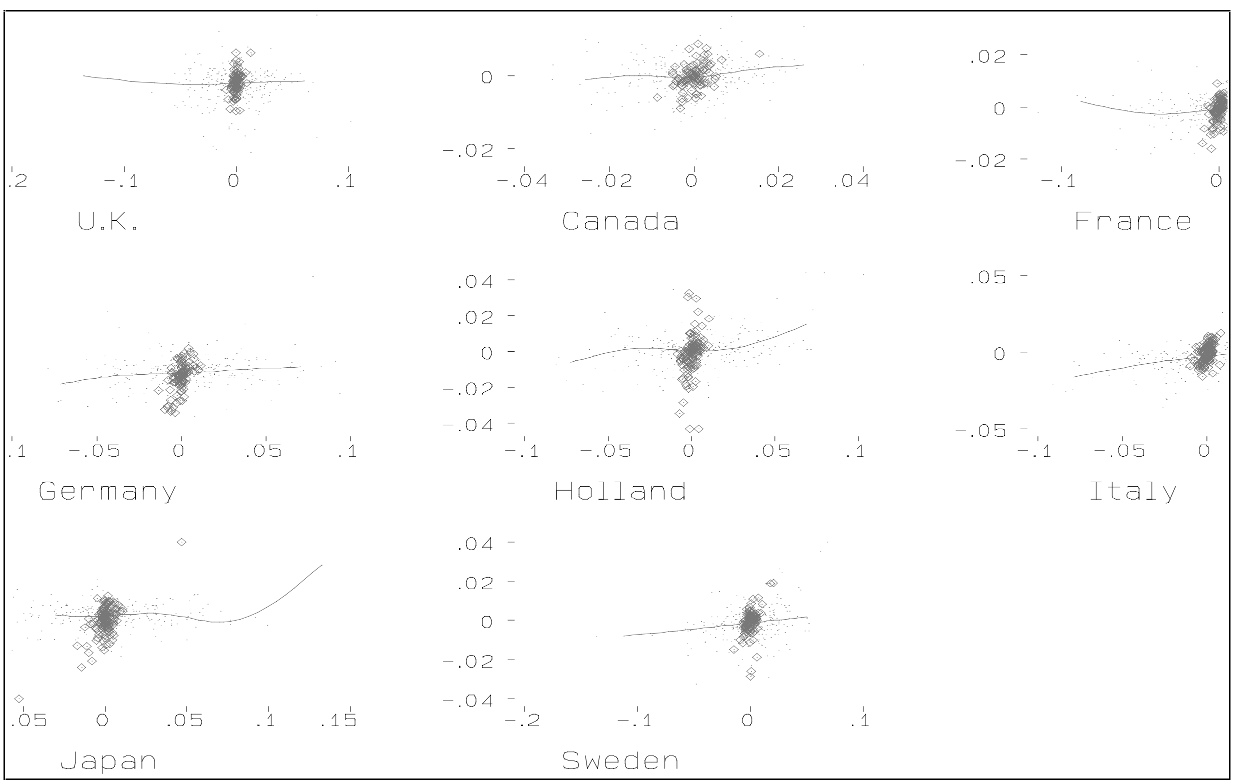

Figure 17: Direct Comparison of ATF and VF, Flexible-Price Benchmark

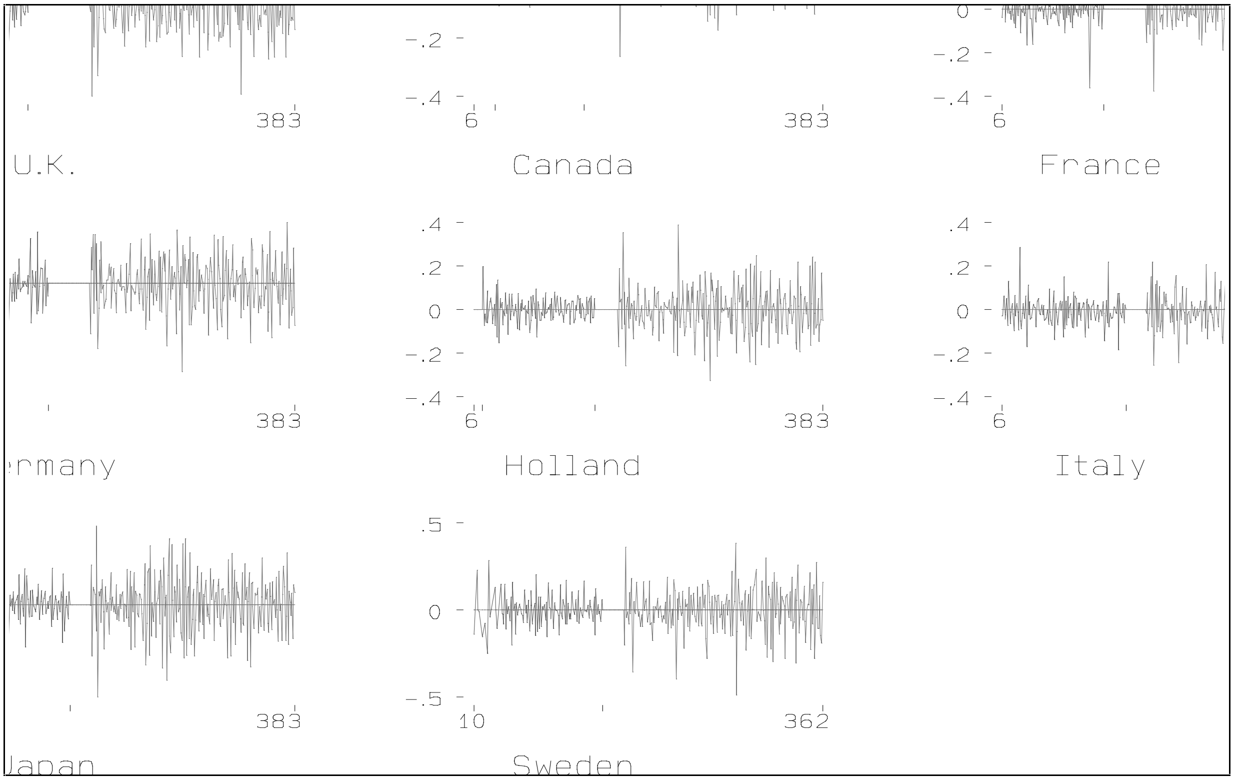

Figure 18: Time series of Traditional Fundamental, Benchmark Sticky-Price Model

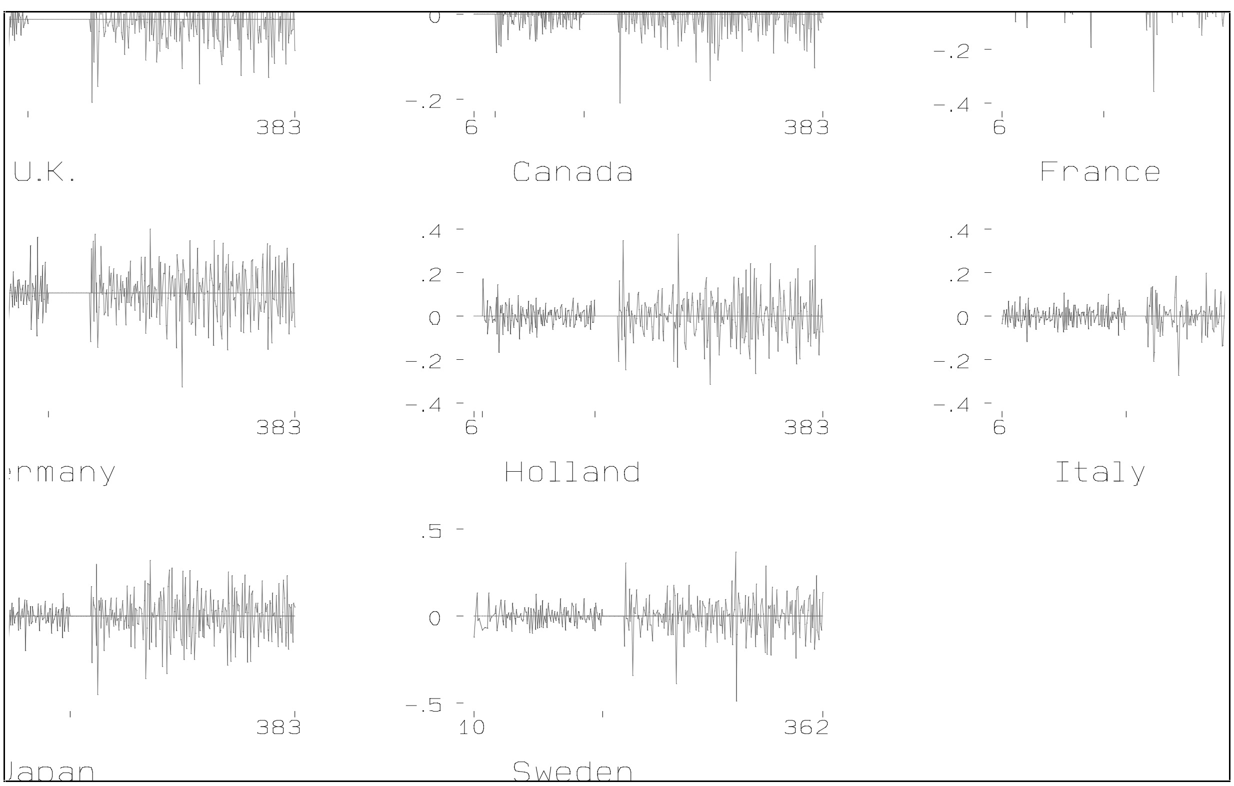

Figure 19: Time series of Augmented Traditional Fundamental, Sticky-Price Model