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The International Policy Center
735 S. State Street
Ann Arbor, MI 48109-3091
USA

Phone: +1 734 763 2599
Fax: +1 734 763 9181
Email: fssp-IPC@umich.edu

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Gary Saxonhouse
University of Michigan

Abstract: Many economists dismiss the role of positive supply shocks as a cause of Japan's deflation. Indeed, they sometimes attribute the long delay in Japan's recovery to the mistaken view that Japan's deflation reflects an acceleration of technological progress. Whatever the current situation in Japan, however, economic history certainly suggests that technological progress can go hand in hand with general deflation. Conducting a VAR analysis using very detailed information about the components of Japan's consumer price index, this paper finds that short-run shocks to Japan's relative price structure persist in the long run. Given this finding, it is possible to conclude that such shocks are real in origin and reflect technological change. As no effort has yet been completed to show the full extent to which technological change is driving short-run relative price change in Japan compared with other factors, and the full extent to which relative price changes are driving aggregate price change compared with other factors, the policy implications of these findings are unclear. What is clear is that it is a mistake to dismiss out of hand the possibility that technological shocks are playing an important role among other forces in Japan's current deflation.

Keywords: Japan's deflation – deflation - technological change

> Teach a parrot the terms "supply and demand" and you've got an economist.
>
> Thomas Carlyle (1795-1881)
> Scottish historian, essayist and social thinker

I. The Classical Identification Problem: How to Account for Price Change: Demand and/or Supply Shocks

It is conventional to think of deflation as intimately associated with inferior economic performance. Of course, this need not be the case. For example, in the late 19th century, new technological and policy innovations permitted a vast expansion in the exploitation of America's abundant natural resources, leading to both falling prices and rapid economic growth (Bordo et al., 2004). This is good deflation!

That deflation can be brought about by a positive supply shock as well as by a negative demand shock calls to mind that the best-known identification problem in econometrics is the disentangling of supply and demand curve shifts to determine the source of a price change (Klein, 1962, pp. 8-92). Consider also the worldwide inflation of the mid-1970s. This is variously seen

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as the result of the negative supply shock brought on by Middle Eastern oil producers in 1973 and thereafter (Hamilton, 1994, pp. 307-308), or alternatively as the by-product of loose monetary policies earlier in the 1970s (Barsky and Killian, 2002). Thirty years after the event it remains a matter for debate whether expansionary or restrictive macroeconomic policies should have been used to cope with the economic distortions of the mid-1970s. With oil prices rising again today this old controversy has emerged anew.

II. Price Deflation in Japan at the Turn of the Twenty-First Century

The Japanese deflation of the past ten years has led to renewed debate about the determinants of price changes. While there is a vast literature suggesting that Japanese disinflation is associated with negative demand shocks (see the summary in Saxonhouse and Stern, 2003), other voices pointing to the late 19th century experience not only of the United States, but also of Germany and the United Kingdom, have suggested positive supply shocks might instead be at work. In particular, former Bank of Japan Governor Masaru Hayami argued:

> …. there is yet another major factor behind worldwide disinflation … a new industrial revolution, and the resulting improvement of productivity. To find answers to what is price stability and an appropriate monetary policy in the face of rapid disinflation due to higher productivity are difficult but positive challenges (Hayami, 2001)

By arguing that Japan may be facing persistent good deflation of uncertain duration, Governor Hayami was suggesting that conventional price level targets or inflation rates targets might not necessarily be the appropriate policy framework for the Bank of Japan. This put the Bank of Japan at odds not only with a large number of academic economists and with many other government agencies within Japan, this position attracted criticism from economists and government officials throughout the world (Svensson, 2003).[1]

III. Sources of Good Deflation

If Japan is experiencing at least some good deflation, what might be its sources. Four obvious candidates include: (1) positive technological shocks at home; (2) positive technological shocks

[1] Hayami has never gone so far to maintain that all deflation is supply side in origin. In addition to supply-side shocks, he has also allowed that there is a "lack of demand" (*Mainichi Shimbun*, January 27, 2003) and that related to this "problems in the banking sector have impaired Japan's credit creation mechanism" (*Jiji Shimbun*, November 23, 2002).

abroad; (3) less concentrated market power in Japan as a result of deregulation in the home market and at the border, and (4) reallocation of resources from declining sectors into increasing returns to scale industries.

Among these four candidates, (2) and (3) seem the least controversial. It now seems well established that a marked acceleration in the rate of technological progress commenced in the United States around 1995 (Oliner and Sichel, 2000; Basu, Fernald and Shapiro, 2001). Similarly, it is clear that deregulation in Japan has led to lower prices for such widely consumed items as gasoline, rice and telecommunication services (OECD, 2004).

In contrast, that the Japanese rate of technological progress may have accelerated during the 1990s and the early years of the 21st century seems the most controversial. Conventional estimates of Japan's multifactor productivity suggest it hardly increased at all between 1992 and 2001. A leading explanation of Japan's almost decade and one-half downturn after 1990 stresses the critical role played by this inexplicable halt in Japan's technological progress (Hayashi and Prescott, 2002). More recent work on Japan's technological progress, however, which allows for increasing returns to scale, imperfect competition, cyclical utilization of capital and labor and reallocation effects finds no such turndown occurred between 1990 and 1998 and a possible increase in the rate of progress after 1998 cannot be ruled out (Kawamoto, 2004). Sectoral reallocation of resources during 1990s plays an important part in this finding. As suggested above in (4), during the downturn of the 1990s the importance of increasing returns to scale industries grew relative to those characterized by decreasing returns.

IV. Central Banks and Good Deflation

To the extent that there are prices falling as a result of supply shocks, to that extent a central bank response may not be required. In light of this and given that central banks typically have a mandate to maintain price stability, there is a very clear interest in having a measure of price change that excludes such items.

If supply shocks are more likely to change the price of goods relative to one another, and demand shocks are more likely to change the price of all goods relative to money, but not to each other, defining a core-price change statistic is useful for better appreciating the imperatives imposed on a central bank (Ball and Mankiw, 1995). Statistical agencies in many countries produce such a statistic by taking the CPI and excluding from it foodstuffs, energy and/or other volatile components.

Since many other items besides foodstuffs and energy experience, at any given time, extreme changes in price relative to other goods, choosing *ex ante* which goods and services to exclude may be a very imperfect way to remove the influence of supply shocks from the CPI. One way to improve on this is to trim the tails (by 15%, 25% or 35%) of a cross-sectional distribution of the changes in the components of the national consumer-price index. The time series of the resulting trimmed index is thought to provide a good measure of demand-side inflation (Bryan and Cecchetti, 1994).

Trimming symmetrically the two tails of a price-change distribution will not yield a different price-change time series from the conventional CPI if the distribution is normal. For the trimmed index to provide new insight, the cross-sectional price-change distribution has to be skewed with right skewness signaling inflation in an untrimmed CPI series while left skewness signals deflation. Other higher order moments are also relevant for the impact of trimming. The sign of the coefficient of excess kurtosis will measure the extent to which the mean of the distribution is larger or smaller than would be the case if the distribution were normal. A positive coefficient of excess kurtosis means the distribution is sharper peaked and fatter tailed than the normal distribution. A negative coefficient may mean a flatter and thin-tailed distribution. An asymmetric, fat-tailed distribution means that the changes in the mean of the distribution may be dominated by shocks to particular items. Changes in the prices of goods and services relative to one another, rather than changes in the price of goods and services relative to money may dominate such a series.

V. What Does the Cross-sectional Distribution of Japan's CPI Look Like?

Using measures, such as those listed in Table 1, scholars have attempted to characterize Japan's price distribution (Shiratsuka, 1997). This work using Japan's CPI disaggregated to 88 components on a monthly basis for the years 1970-1997 finds Japan's monthly price-change distribution mostly skewed in a rightward direction. The price-change distribution appears to be almost always leptokurtic (fat-tailed) and often dramatically so. There does appear to be a positive association between skewness and the rate of CPI change. Of particular interest, in 1995, 1996 and 1997, mild deflation is associated with a leftward skewness of price-change distribution (Mio and Hiyo, 1999). If supply shocks were temporary and prices flexible, the latter correlation should not be found. In a world of highly flexible prices, if prices of some items go down, purchasers then have more to spend on other items forcing those prices up. It is not clear whether the average should be influenced at all (Ball and Mankiw, 1995).

Table 1

Standard Deviation = $s = \sqrt{\sum_{i=1}^{n} w_i (x_i - m)}$

Coefficient of Skewness = $\sum_{i=1}^{n} w_i \frac{(x_i - m)^3}{s^3}$

Coefficient of Excess Kurtosis = $\sum_{i=1}^{n} w_i \frac{(x_i - m)^4}{s^4} - 3$

$w_i \equiv$ weight of item in the CPI

VI. Further Disaggregation of Japan's CPI

The 88 components in Japan price-change distribution can be further disaggregated. In 1970 there were 329 sub-components of Japan's CPI. Over time the number of sub-components in the CPI has grown and changed with items dropped and added. The total number of sub-components in the CPI is now 613. Table 2 provides information on when new items have been added to the CPI. The two most recent items added (in 2002) were interconnection charges for the internet and PC printers. Significantly, PC printers are estimated to have fallen in price in Japan by two-thirds since 2000. Table 3 provides an example of how much extra detail the disaggregation of one of the 88 components provides.

Table 2

Introduction of New Items to the Japanese CPI by Year

1970: 329 1985: 45

1972: 2	1990: 31
1975: 63	1995: 36
1980: 45	2000: 55
1981: 4	2002: 2

Of the 329 subcomponents since 1970, 285 are still in the index. Using these 285 series for 1970 through February 2000 an attempt is made here to assess whether and how relative price shocks account for changes in Japan's CPI over this period. The results of the first part of this analysis are presented in Figures 1, 2 and 3. Figures 1 and 2 show there is a strong positive correlation between the change in the overall CPI series and the changes in the standard deviation of its components, and a positive correlation between changes in the overall CPI series and changes in the coefficient of skewness. These relationships hold both when there is deflation as well as when there is inflation. In contrast, in Figure 3, the relationship between CPI change and the coefficient of excess kurtosis is either non-existent or negative depending on which method of seasonal adjustment is used.[2]

Table 3
An Example of Disaggregation of the CPI

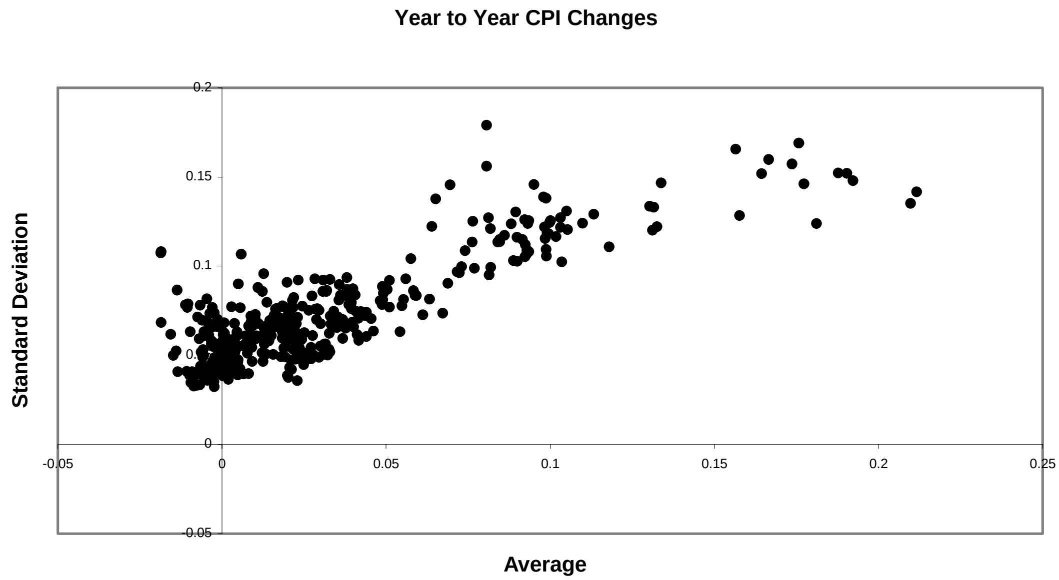
School fees (one of the 88 components of the CPI)
School fees disaggregated into its subcomponents
PTA (primary school) membership fees (since 1970
PIA (junior high school) membership fees (since 1970)
Junior high school fees, private (since 1970
High school fees, public (since 1970)
High school fees, private (since 1970)
College and university fees, national (since 1970)
College and university fees, private (since 1970)
Junior college fees, private (added in 1995)
Kindergarten fees, public (since 1970)
Kindergarten fees, private (since 1970)

[2] Seasonal effects have been muted by using two alternative methods: (1) year-over-year monthly changes; and 2) X-12 ARIMA with constant and level effects. Seasonal adjustment of Japan's CPI is necessary because, unlike the United States, CPI seasonal adjustment is done by Japan's statistical agencies only at the most aggregate level.

These skewness and standard deviation findings are consistent with the view that supply shocks play a role in driving changes in Japan's CPI. The skewness results allow the easiest interpretation. Positive extreme shocks are helping to cause inflation; negative extreme shocks are helping to cause deflation. Given a price-change distribution with a positive relationship between skewness and price change, there should be a positive relationship between price changes and the standard deviation, when skewness is positive, and a negative relationship when skewness is negative. A large standard deviation magnifies the effect of skewness on price change in whichever direction the skewness points. The positive correlation between CPI change and the standard deviation seems to indicate that a decline in extreme relative price changes has helped to drive down Japan's inflation rate. Inspection of Figure 1 also indicates that as inflation turns to deflation, the positive correlation between price change and the standard deviation turns negative. Had Japan experienced more deflation, the scatter of points in Figure 1 might have been more distinctly v-shaped and centered about a Y-axis. What evidence is available, however, does seem consistent with the view that extreme relative price changes have helped to push up Japan's rate of deflation.

In the same way that skewness in the price-change distribution when positive can be expected to help generate a positive relationship between price change and the standard deviation and a negative relationship when it is negative, so also should the sign of the relationship between price change and excess kurtosis vary depending on whether the price-change distribution is

Figure 1
Standard Deviation and Average Price Change (both weighted)



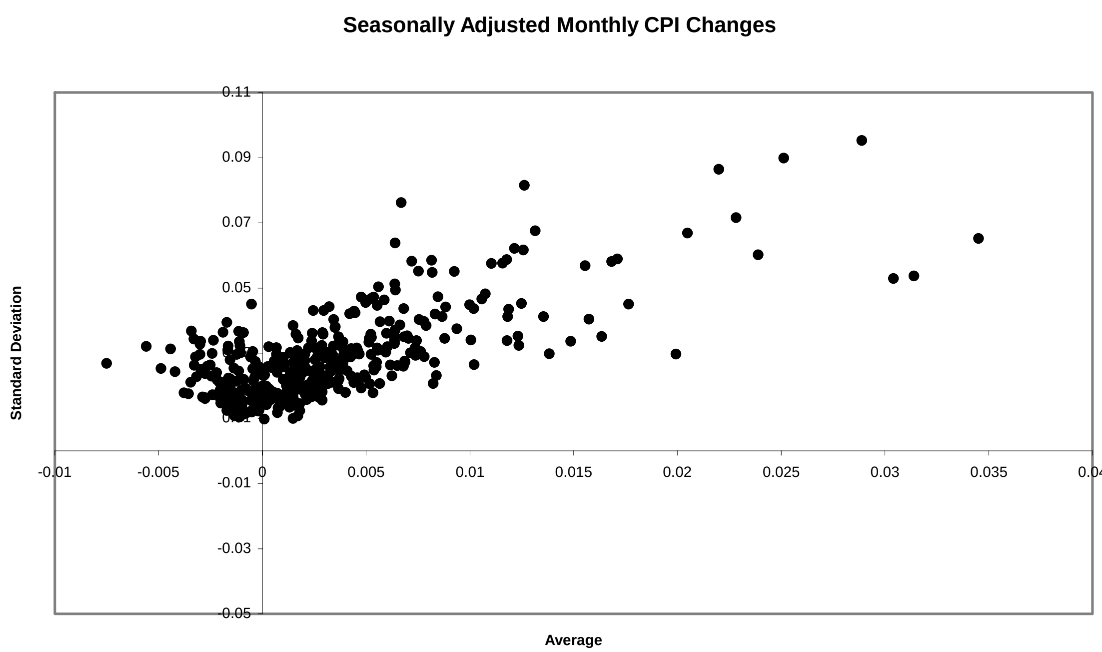
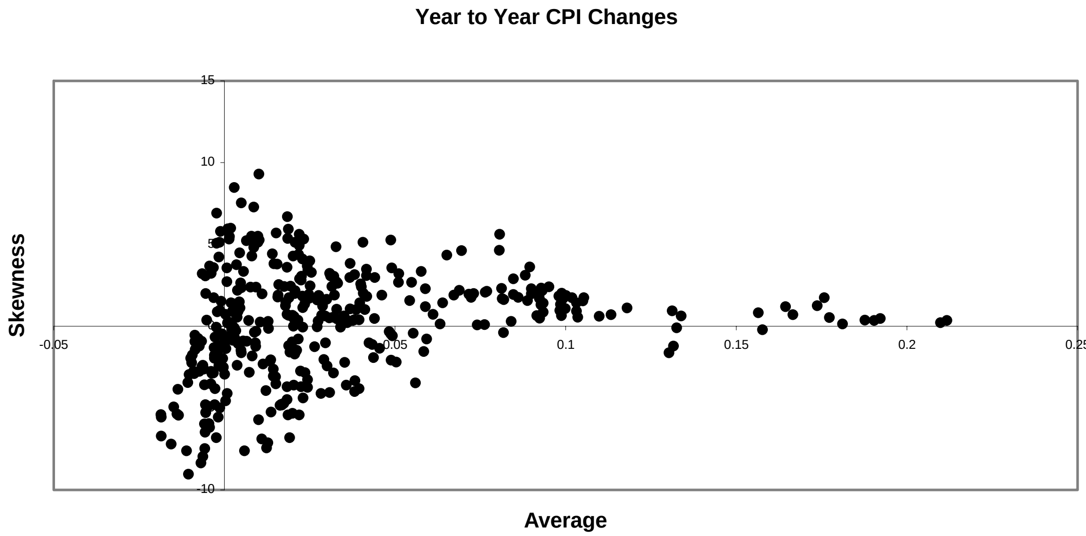


Figure 2
Coefficient of Skewness and Average Price Change (both weighted)



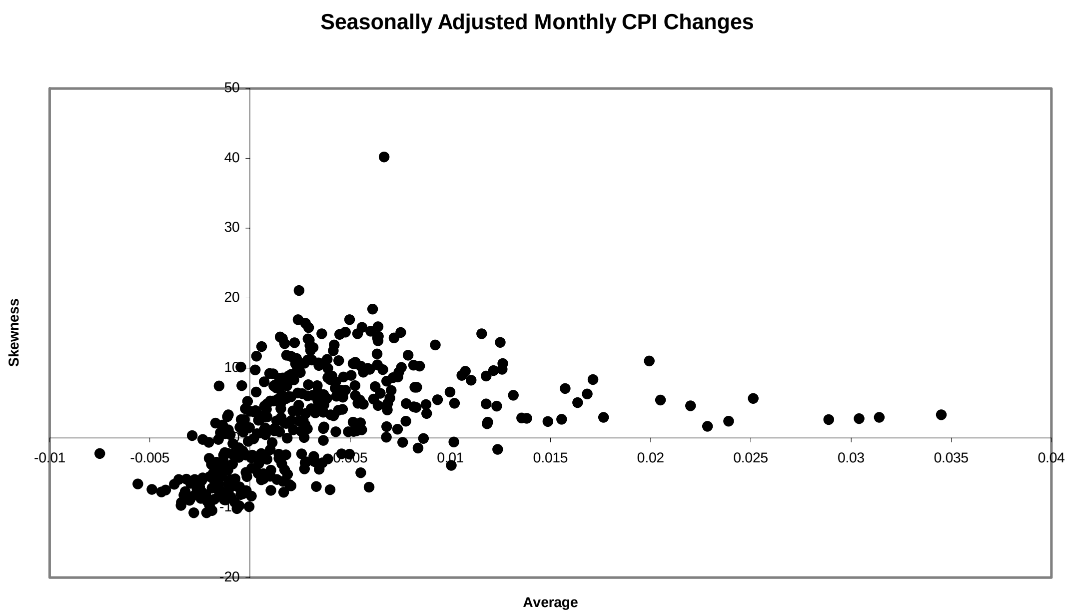
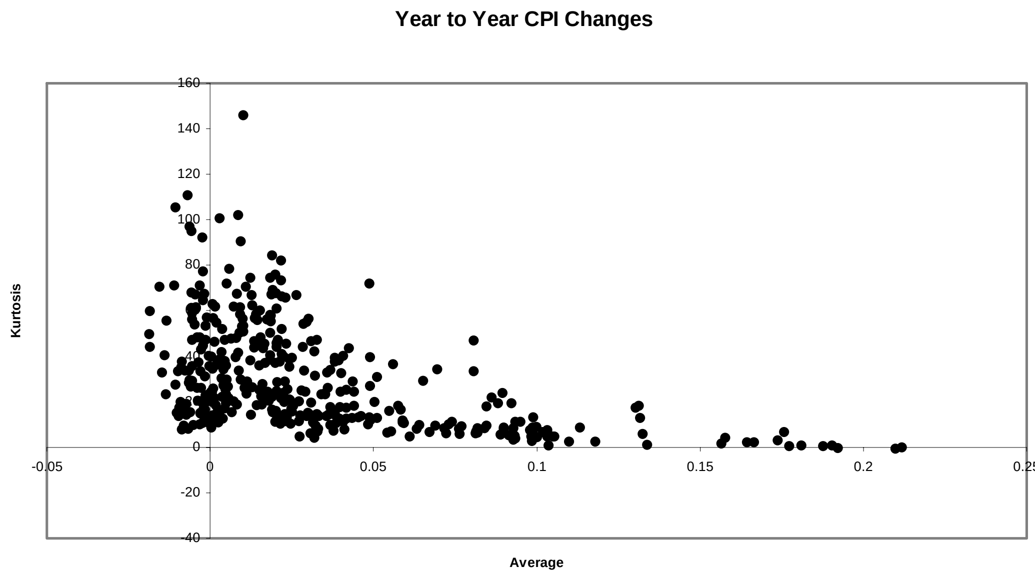
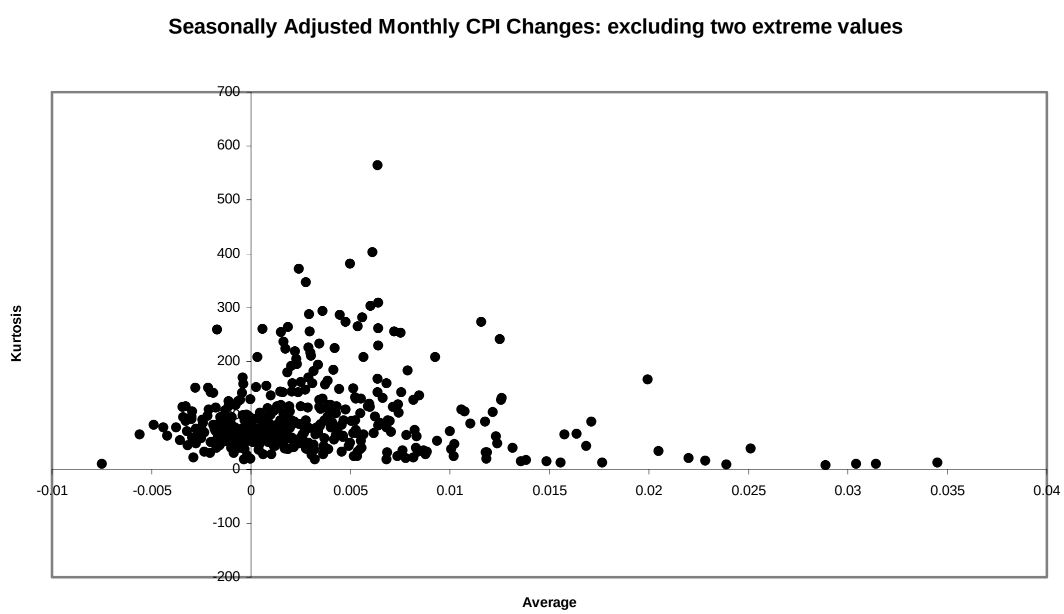


Figure 3
Kurtosis and Average Price Change (both weighted): excluding two extreme values





skewed in the positive or negative direction. The fatter the tail of the distribution, the more the effect of skewness on price change should be magnified. The simple correlations, however, between price change and excess kurtosis do not confirm this expectation.

As noted, when examining the relationship between the coefficient of excess kurtosis and price change, the method used to remove seasonal effects can make a considerable difference. The price-change distribution is leptokurtopic throughout each month of the entire sample. When the relatively simple method of using year-to-year monthly changes is used to take out seasonal effects, there is a negative relationship between price change and the coefficient of excess kurtosis. As seen in the top panel of Figure 3, this negative relationship is greatly strengthened by a small number of outlier observations. Even in the absence of these observations the negative correlation does persist and therefore continues to suggest that the flatter-peaked and thinner-tailed the distribution, the greater the price change. To some extent, this does undercut the argument that extreme observations are driving Japanese price change. In contrast, the results obtained when X-12-ARIMA is used to remove seasonal effects suggest no relationship at all between price change and the coefficient of excess kurtosis. This is consistent with the presence of positive and negative skewness in the overall sample. The absence of , however, of even a hint of a v-shaped pattern in the bottom panel of Figure 3 is surprising.

Table 4 presents the correlation coefficients for the relationships just discussed, broken down by time period. The results suggest some change in the price-change distribution over the past dozen years (1993-2004). Some of these changes are consistent with extreme values of the price-change distribution playing a more significant role in moving Japan's rate of inflation and deflation during this period. The much stronger correlation between price change and the coefficient of skewness is a clear indication of this. So also is the weaker correlation between price change and standard deviation during the past dozen years. Since the size of the standard deviation is both positively and negatively correlated with price change depending on the direction of skewness, it is not surprising that in a period where there is some negative skewness the overall correlation between price change and the standard deviation falls.

Table 4
Correlations between the Moments of the Price-change distribution

Correlation Coefficients for Year-over-Year Monthly Changes

With AVE.	STD. DEV.	SKEW	KURT
1970-1992	0.8374*	0.1872*	-0.553*
1993-2004	0.2737*	0.4843*	-0.0654
1970-2004	0.8526*	0.2252*	-0.4896*

Correlation Coefficients with Seasonal Effects Removed by X-12-ARIMA

With AVE.	STD. DEV..	SKEW	KURT
1970-1992	0.703*	0.3641*	-0.0395*
1993-2004	0.4655*	0.6763*	0.2975*
1970-2004	0.7145*	0.4114*	-0.0002

* correlation coefficient is significant 95% or higher confidence interval

The results of the correlation between price change and the coefficient of excess kurtosis suggest a somewhat more dramatic break from the past during the past dozen years. The year-to-year monthly price changes have a negative correlation with the coefficient of excess kurtosis prior to 1992. After 1992, the correlation becomes statistically insignificant. The tails of the price-change distribution no longer become fatter as deflation emerges. When X-12-ARIMA is used to remove seasonal effects in the price-change data, the price-change-coefficient of excess kurtosis correlation goes from being statistically insignificant to being positive and statistically significant for the period after 1992. Since there has been both positive and negative skewness in the price-change distribution over the past dozen years, a priori, one should have expected the correlation between price and excess kurtosis to fall compared to earlier periods. That it rises is puzzling.

VII. Do Relative Price Changes Reflect Long-Term Technological Change?

The price-change distribution can be skewed and leptokurtopic and its mean can vary with its standard deviation, and yet the consequences of any supply shock might be short-lived (Ball and

Mankiw, 1995 and Parsley, 1996). The price changes observed for Japan and the particular shape of its price-change distribution may reflect nothing more than short-term frictions and misperceptions in the economy. Whatever supply shock occurs could reverse itself relatively quickly. If this is the case, the findings on the price-change distribution that have just been presented might not bear on Governor Hayami's analysis of Japan's deflation problem or the implications of that analysis for central-bank policy (Romer, 2001, pp. 302-312). If, however, many of the shocks that generate the special shape of Japan's relative price distribution are real in origin and reflect technological change, then the contemporaneous correlation found between the mean and the standard deviation, the coefficient of skewness and the coefficient of excess kurtosis might be expected to persist in the long run (Balke and Wynne, 2000).

VIII. Searching for Long–Term Impact

Using a VAR model the short-term and long-term relationship between the mean and the standard deviation, the coefficient of skewness and the coefficient of excess kurtosis of Japan's price-change distribution will be explored.[3] These relationships will be examined using the correlation coefficients of VAR forecast errors at different horizon forecasts. If the series being examined are stationary, then the correlation coefficient of the forecast errors will converge to an unconditional correlation coefficient as the forecast error goes to infinity. If some of the series used in the VAR are not stationary, the estimates of the correlation coefficient might not converge, but can still be estimated consistently for a fixed forecast period (den Haan, 2000).

Monthly observations on CPI sub-components available from January 1970 through February 2004 will be used for this empirical work. The VAR is given by

$$(1) \qquad Z_t = D + P_t + Ft^2 + \sum_{k=1}^{n} J_k Z_{t-k} + \varepsilon_t$$

where

Z ≡ q-vectors containing selected moments characterizing the price-change distribution

D, P and F ≡ q-vectors of constants

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[3] The methods used here follow the approach used in den Haan (2000) and adopted and usually fully adapted in Nath (2004).

J ≡ q x q matrix of autoregressive coefficients at lag k

ε_t ≡q-vector of innovations assumed to be serially uncorrelated but possibly correlated with each other

The M-period ahead forecast error for selected statistics characterizing the price-change distribution is given by

(2) $\ell_{t+M,t} = \psi_{t+M} - E\psi_{t+M}$ where

Ψ ≡ a selected statistic characterizing the price-change distribution

In order to examine long-term relationships, the correlation between the mean and the standard deviation, the coefficient of skewness and the coefficient of excess kurtosis of the Japanese price-change distribution are calculated over various forecast horizons using the VAR model.[4]

The VAR model just outlined is estimated: (1) with and without linear and quadratic terms; (2) with and without the unit root imposed; (3) with lag lengths that vary from 1 to 24 months; and (4) for three different time periods.[5] Decisions on lag lengths and whether to include linear and quadratic terms are based on the Akaike Information Criterion.[6] Bootstrap methods are used to construct 90% confidence intervals around the estimates of the correlation of the forecast errors. Table 5 explains the characteristics of the estimated VARs. The results of this empirical work are presented in Figures 4-9.

In each of the three panels in Figures 4- 9, there are three lines. The middle line connects estimated correlation coefficients at each forecast horizon. The lines above and below define the 90% confidence interval for these estimates. Notwithstanding that three time periods are examined and that the analysis is conducted both without and with the unit root imposed, overall, there is considerable evidence for a positive correlation between average price change

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[4] A money supply term is also included as part of this analysis.

[5] Unit roots have been tested for using Augmented Dickey-Fuller and Ng-Perron. These tests reject the null unit-root hypothesis for all variables used in this analysis except average price change.

[6] The analysis here has also been conducted with decisions on lag lengths and the inclusion or exclusion of linear and quadratic terms based on the Akaike Information Criterion. While many of the details of the analysis change dramatically (in particular the length of the lags), the conclusions of the analysis are in no significant way different from what is found when the Schwartz Information Criterion is used. This entire analysis has also been done on data seasonally adjusted by X-12-ARIMA without substantially altering the findings.

and the coefficient of skewness that is not temporary, but that holds in the long run. The same is not the case for the other moments of the price-change distribution. In none of the six cases is there long-term correlation between the coefficient of excess kurtosis and price change. This is entirely consistent with what is to be expected on theoretical grounds and not surprising even though there is evidence of a short-term negative correlation. In those two of the six cases where the entire sample from 1970 to 2004 is used to estimate the VAR model, there is evidence of a positive long-term correlation between the standard deviation and price change. In those cases where the VAR model is estimated with samples where inflationary and deflationary sub-periods are more evenly matched, no such positive long-term correlation is found. Again this is consistent with theory given the finding of a long-term positive relationship between skewness and price change.

IX. Finale

The correlation coefficients of VAR forecast errors at different forecast horizons, as presented in Figures 4-9, provide strong, though not unanimous, evidence that the positive short-run relationships between price change and the coeffcient of skewness and to a much lesser extent between price change and the standard deviation persist in the long run. To the extent that these relationships persist in the long run suggests that shocks responsible for short-run price change are often real in origin and reflect technological change.

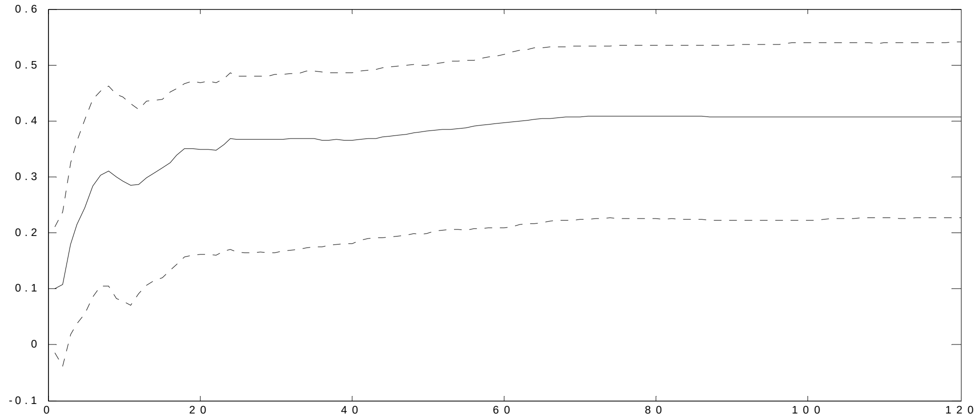
As no effort has yet been made to show the full extent to which technological change is driving short-run relative price change in Japan and the full extent to which relative price changes are driving aggregate price change, the policy implications of the paper are unclear. What is clear is that it is a mistake to dismiss out of hand the possibility that technological shocks are playing an important role among other forces in Japan's current deflation.

Table5 Characteristics of Estimated VARs

Data	Pair with Mean	Lag #	Trend	Figure
Year over year, monthly change, from 1970, no unitroot	Standard Deviation	13	Linear, quadratic	4
	Coefficient of skewness	14	Linear, quadratic	4
	Coefficient of excess kurtosis	17	Linear, quadratic	4
Year over year, monthly change, from 1970, unit root imposed	Standard Deviation	24	Constant	5
	Coefficient of skewness	24	Constant	5
	Coefficient of excess kurtosis	24	Constant	5
Year over year monthly change, from 1986, no unit root	Standard deviation	14	Linear	6
	Coefficient of skewness	17	Linear	6
	Coefficient of excess kurtosis	13	Linear	6
Year over year monthly change, from 1986, unit root imposed	Standard deviation	13	Constant	7
	Coefficient of skewness	13	Constant	7
	Coefficient of excess kurtosis	13	Constant	7
Year over year monthly change from 1993, no unit root	Standard deviation	24	Linear, quadratic	8
	Coefficient of skewness	24	Linear, quadratic	8
	Coefficient of excess kurtosis	24	Linear, quadratic	9
Year over year monthly change from 1993, unit root imposed	Standard deviation	24	Linear	9
	Coefficient of skewness	24	Linear	9
	Coefficient of excess kurtosis	24	Linear	9

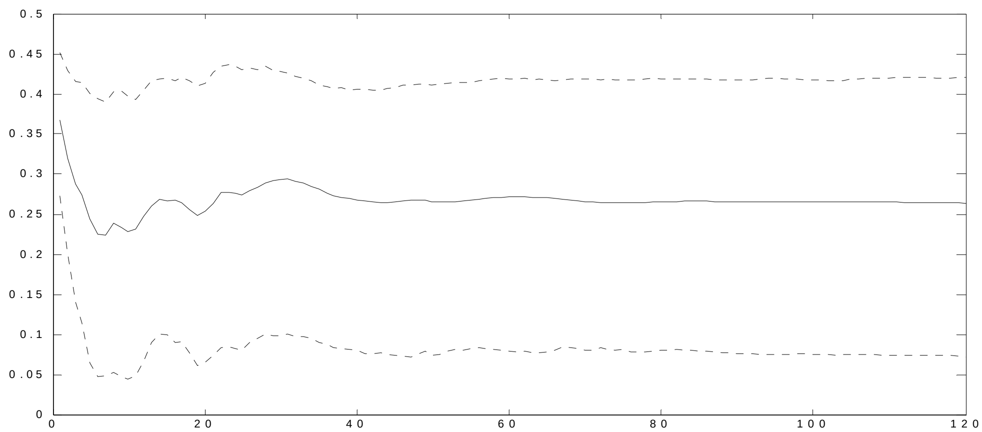
]Figure 4

a. Correlation between first and second moments 70Y Level VAR



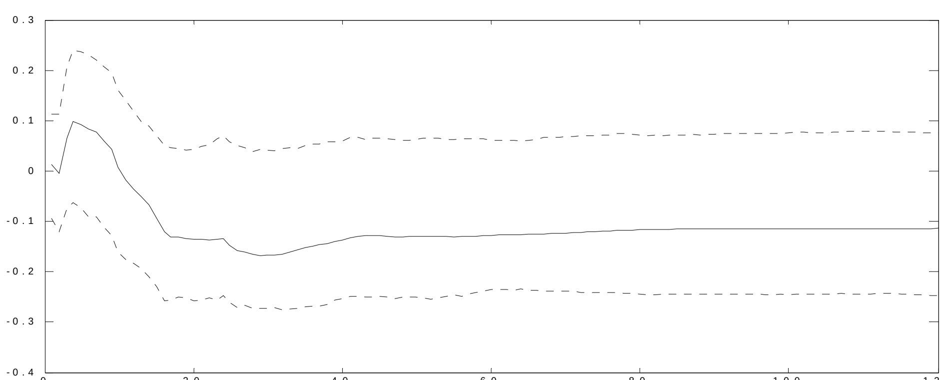
Forecast Horizon (months)

b. Correlation between first and third moments 70Y Level VAR



Forecast Horizon (months)

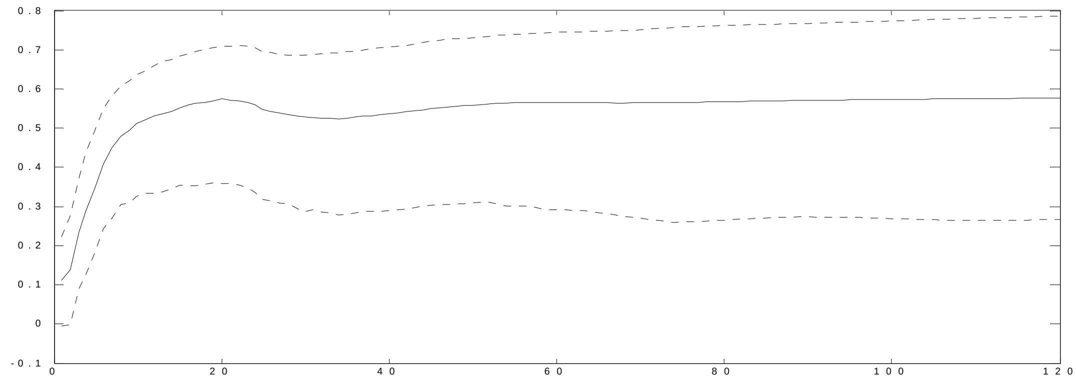
c. Correlation between first and fourth moments 70Y Level VAR



Forecast Horizon (months)

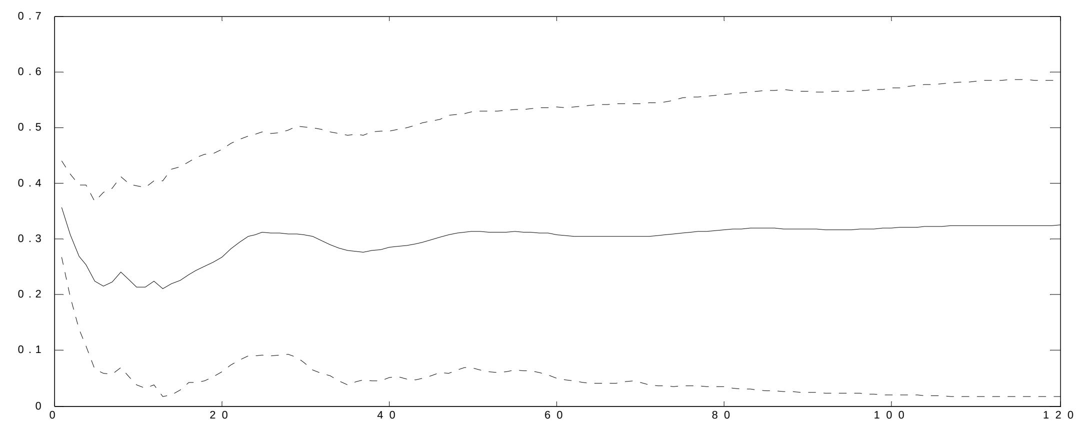
Figure 5

a. Correlation between first and second moments 70Y Differenced VAR



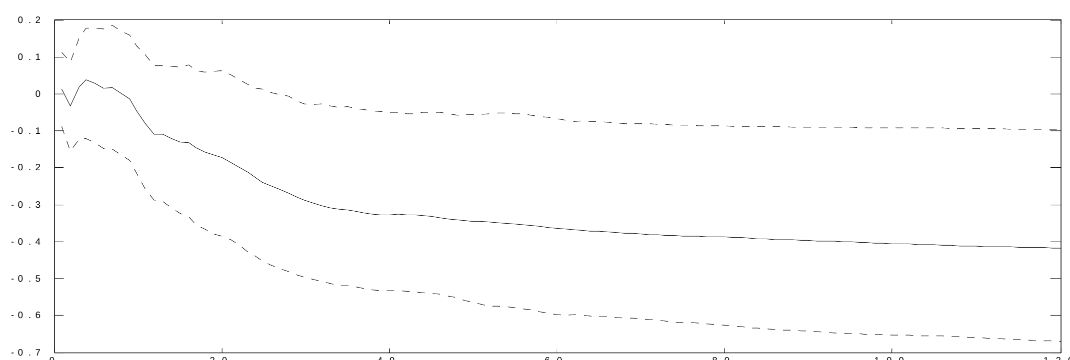
Forecast Horizon (months)

b. Correlation between first and third moments 70Y Differenced VAR



Forecast Horizon (months)

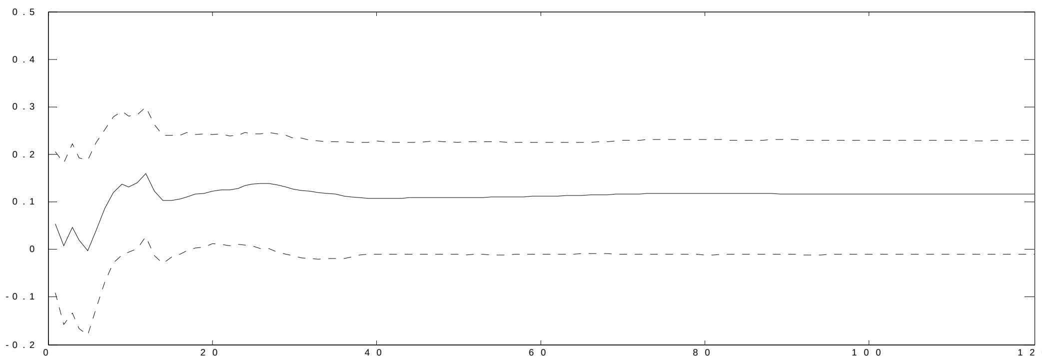
c. Correlation between first and fourth moments 70Y Differenced VAR



Forecast Horizon (months)

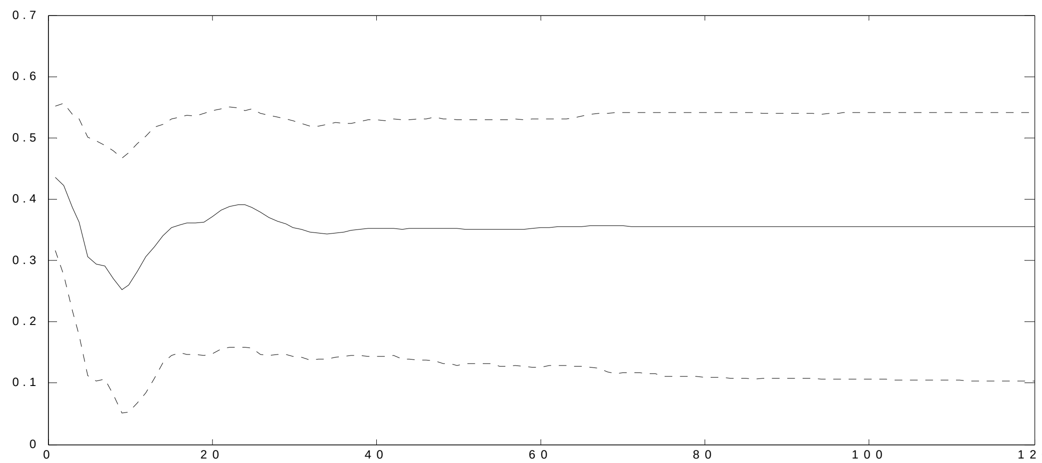
Figure 6

a. Correlation between first and second moments 86Y Level VAR



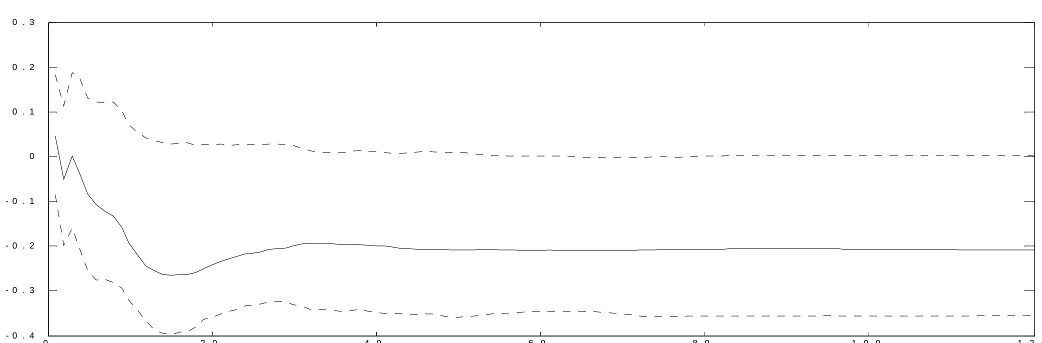
Forecast Horizon (months)

b. Correlation between first and third moments 86Y Level VAR



Forecast Horizon (months)

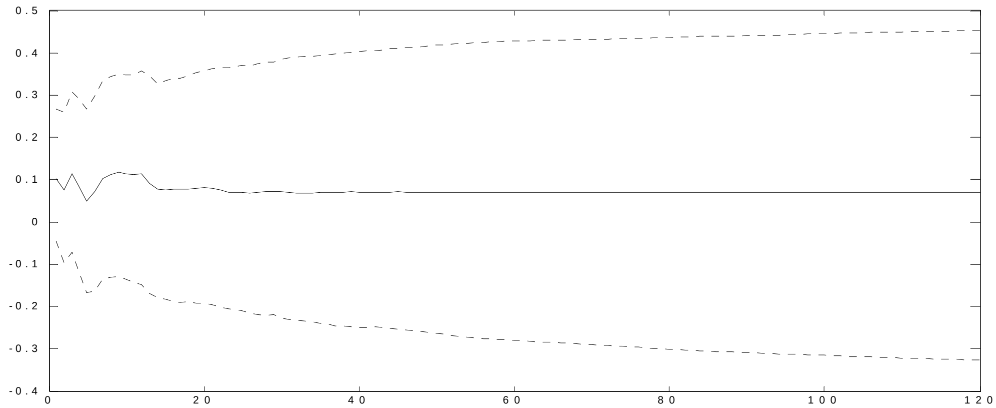
b. Correlation between first and fourth moments 86Y Level VAR



Forecast Horizon (months)

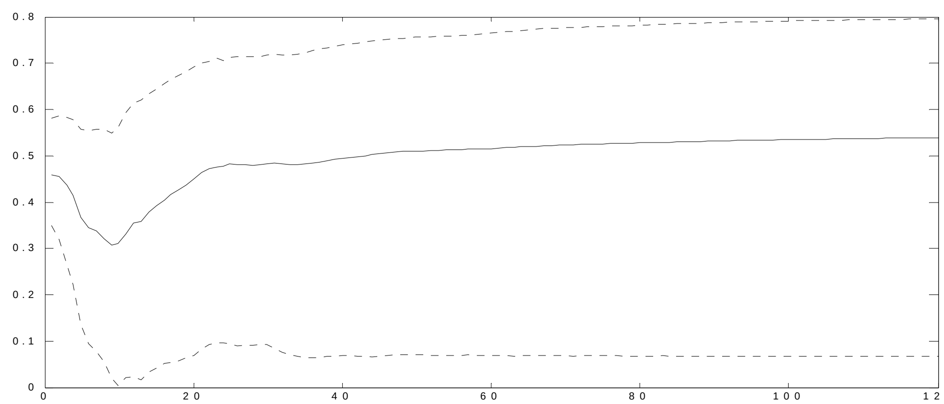
Figure 7

a. Correlation between first and second moments 86Y Differenced VAR



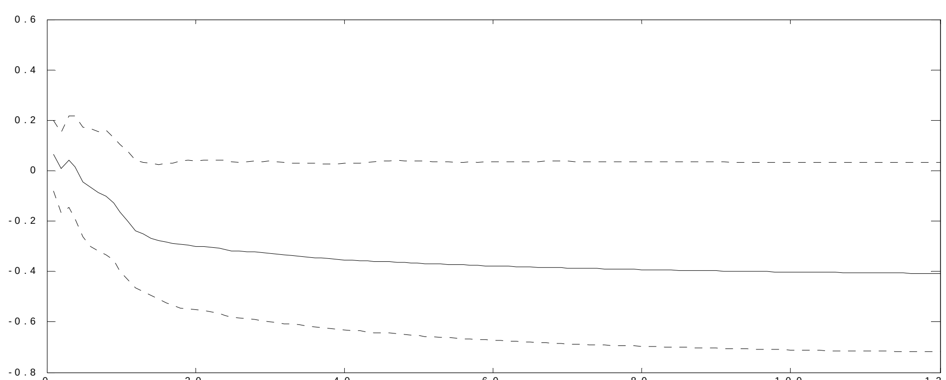
Forecast Horizon (months)

b. Correlation between first and third moments 86Y Differenced VAR



Forecast Horizon (months)

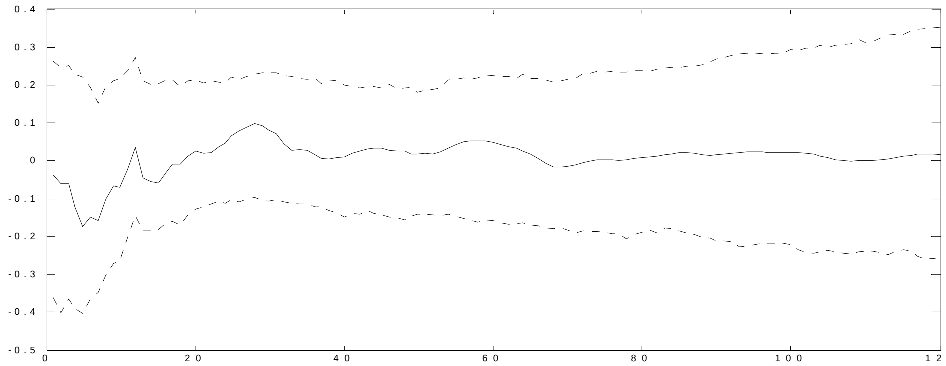
c. Correlation between first and fourth moments 86Y Differenced VAR



Forecast Horizon (months)

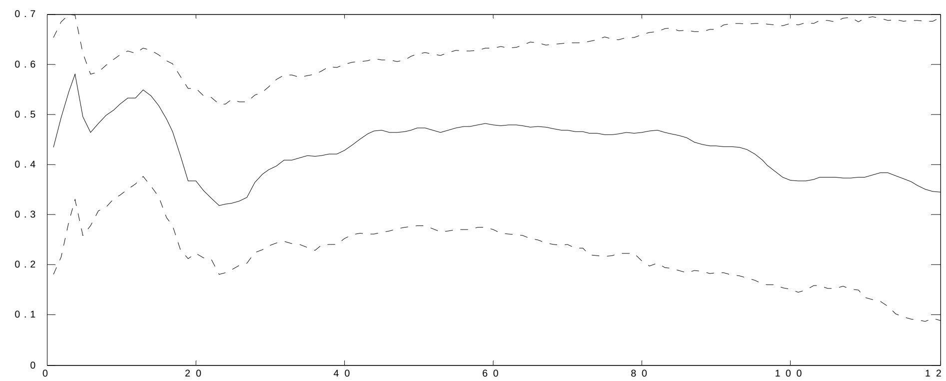
Figure 8

a. Correlation between first and second moments Y93 level VAR



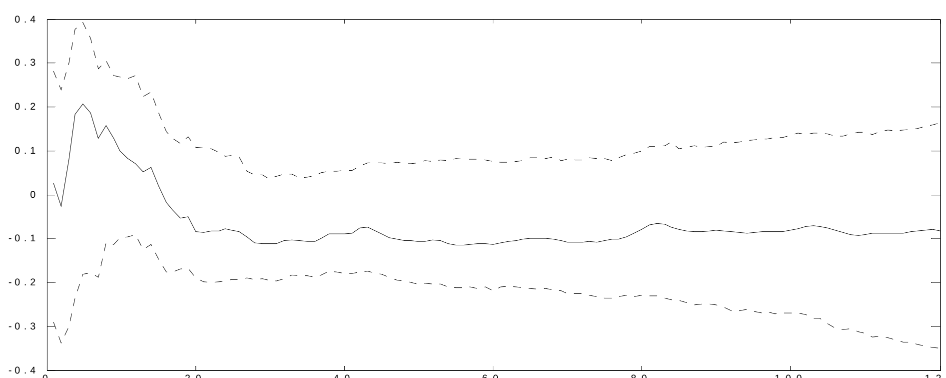
Forecast Horizon (months)

b. Correlation between first and third moments Y93 Level VAR



Forecast Horizon (months)

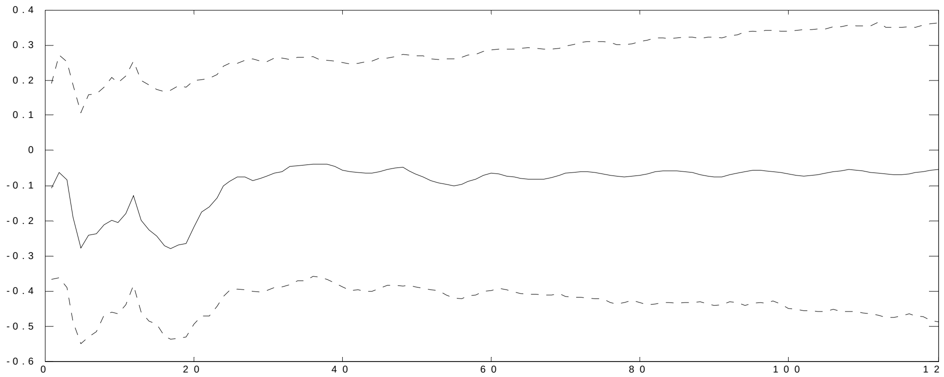
c. Correlation between first and fourth moments Y93 Level VAR



Forecast Horizon (months)

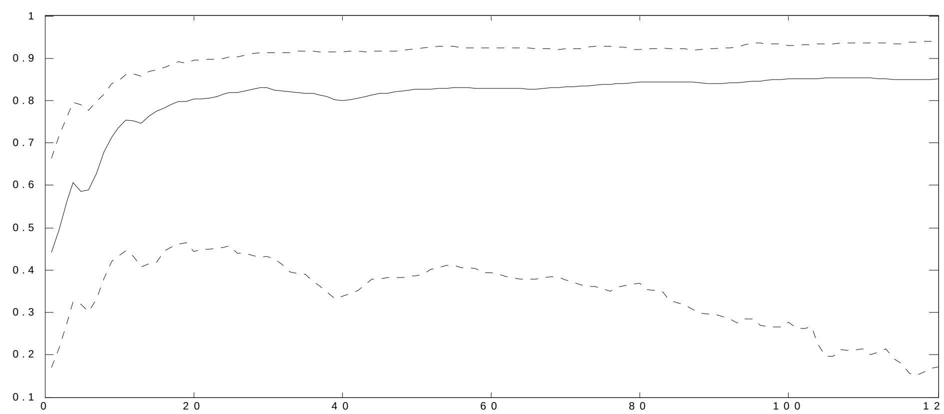
Figure 9

a. Correlation between first and second moments



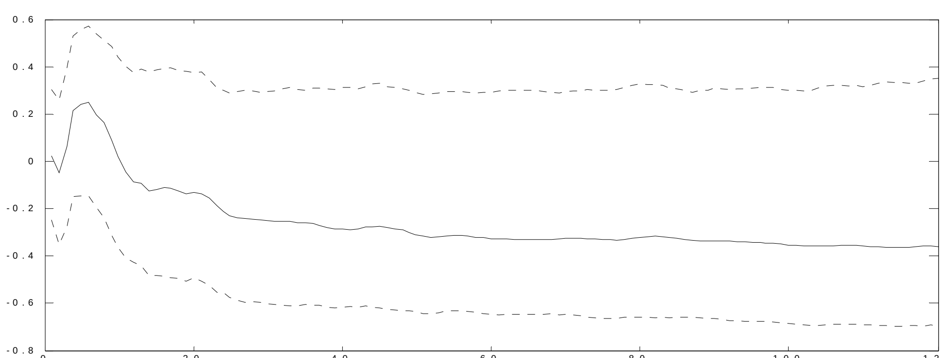
Forecast Horizon (months)

b. Correlation between first and third moments



Forecast Horizon (months)

c. Correlation between first and fourth moments



Forecast Months (months)

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