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RELATIVE PRICES: A CASE FOR FOUR
PERCENT SOLUTION**

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Abstract

Unlike earlier literature that documented positive association between inflation and the dispersion of relative prices over time, the empirical evidence from this study suggests that the relative price dispersion increases in response to the deviation of inflation from certain threshold/target level in either direction rather than the inflation per se. More importantly, the inflation rate at which the dispersion of relative prices is minimized turn out to be 4 percent for US and Japan; hence, supporting the proposal of 4 percent inflation target for both the countries.

Keywords: *Inflation uncertainty, relative price dispersion, rolling cointegration, threshold inflation*

JEL Codes: *E30; E31; E52*

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INTRODUCTION

In literature, a large number of theoretical studies have demonstrated that higher rate of inflation results in higher variability of relative prices and inflation uncertainty. Theoretically, the relationship between inflation and relative price variability is explained by models based on misperceptions or incomplete information (Lucas, 1973; Hercowitz, 1981; and Cukierman, 1983). The models based on incomplete information demonstrate that under certain conditions the firms with price elastic supply adjust quantity in response to demand shocks whereas the firms whose supply is inelastic adjust prices in response to such shocks. Hence, demand shocks that generate higher inflation trigger larger variability or dispersion in relative prices.

The association between inflation and inflation uncertainty/variability, highlighted by Friedman (1977), arises from the public's perception about the erratic policy responses by monetary authority to large changes in prices (Ball, 1992). More precisely, this relationship is built on the premise that sharp rise in inflation produces strong pressure on the policy makers and as a result, 'policy goes from one direction to other', thereby, generating wide variation in actual as well as expected inflation.¹ Under these circumstances, predicting both the longer term drift in inflation and its short term movements become more difficult.

Extending this strand of literature, Shoosmith (2000) points out that as inflation rises 'component inflation measures are not only more variable at each point in time, but also more dispersed *over time*'. He argued that component price indices are likely to drift apart more significantly during the period of high inflation (as compared to low

¹ Number of empirical studies provide evidence in favor of the hypothesis that higher rate of inflation is associated with larger inflation uncertainty (see e.g., Daal *et. al.*, 2005; Thornton, 2008; Herwartz and Hartmann, 2012).

inflation period), hence, resulting in larger dispersion of relative prices *over time*. Note that such measure of dispersion is different from the traditional measure which is measured as variance of cross-sectional distribution of price changes at a given point of time.² In order to empirically verify this, Shoesmith (2000) examined the number of cointegrating relations among component price indices, as large (less) number of significant cointegrating relations implies less (large) dispersion of relative prices over time. Using Johansen's (1991) methodology, the study finds relatively lesser number of significant cointegrating relations among US CPI component indices during the period of high inflation as compared to the high inflation period.

On the contrary, Scharff (2007) discovers relatively less number of significant cointegrating relations among component price indices of US CPI during the period of moderate inflation using the sample period considered by Shoesmith (2000). She attributed this contradicting evidence to the fact that Shoesmith (2000) uses component indices which covers only 70 percent of the US CPI. She further corroborates her findings with evidences obtained from a set of countries and concludes that counting number of significant cointegrating relations in a system of component price indices is not an appropriate method to examine the response of relative price dispersion to inflation.

In this context, we argue that the traditional approach of simply bifurcating the sample into high and low inflation regime, based on mean inflation, and then comparing the number of significant cointegrating relationships among component price indices during these two regimes is not an appropriate approach. In particular, under such approach, the dispersion of relative prices is related to the rate of inflation per se. However, theoretically, the relative price dispersion over time is

² From the theoretical point of view, the measure of relative price dispersion measured *over time* highlights another aspect variability associated with inflation as emphasized by Friedman (1977) and Ball (1992).

perceived to increase in response to the deviation of inflation from certain threshold/target level in either direction rather than inflation per se. In other words, higher levels of inflation above certain threshold tend to increase the relative price dispersion and lower levels inflation below that threshold also tend to increase the dispersion of relative prices. A number of recent theoretical and empirical studies have demonstrated that the strength of association between inflation and relative price dispersion is largely determined by the magnitude of deviation of inflation from certain threshold level in either direction (Fielding and Mizen, 2008; Choi, 2010; Choi and Kim, 2010; Rather *et. al.*, 2014a). In particular, Fielding and Mizen (2008) and Choi (2010) have shown that the response of relative price dispersion to inflation is U-shaped; implying that larger deviation of inflation will result in higher dispersion of relative prices. This finding suggests that in a system of price indices, the number of cointegrating relations is expected to decline (which implies rise in price dispersion) as inflation departs far off from the threshold level in either direction. In other words, the number of cointegrating relations is likely to be less (i.e., the number of stochastic trends is expected to be more) during the periods of high as well as low inflation and maximum when inflation is closer to the threshold level.

It is important to note that the impact of inflation on the dispersion of relative prices is considered as the prime channel through which inflation affects the real sector of an economy. In the new Keynesian dynamic general equilibrium models, the larger dispersion in relative prices due to inflation is considered to be the root cause of all distortionary real effects of inflation (Green, 2005). The findings of these models advocate that monetary authorities must be committed to ensure price stability mainly because changes in aggregate prices cause larger variability in relative prices (see e.g. Woodford, 2003; Becker and Nautz, 2012). In this context, Blejer and Leiderman (1980) emphasized four channels through which higher relative price variability affect the growth rate of real output: (i) it reduces the information content of relative

prices and drives a wedge between marginal rates of transformation and substitution, which results in misallocation of resources and inefficiency; (ii) it leads to large search activities which involves costs in terms of time and resources; (iii) it results in shortening of optimal contract length and more frequent revisions in existing contracts, thereby increasing the cost of contracting; and (iv) it impedes the efficient allocation of resources to the extent that the costs of higher price variability are differentially distributed among firms.

In this paper, using the CPI data from US and Japan, we first calculate the number of significant cointegrating relations in the system of component price indices for a sequence of rolling subsamples. Next, we compare the number of significant cointegrating relations obtained from each rolling subsample with the average inflation rate of the corresponding period. The advantage of this procedure is that it provides scope for capturing the dynamic relationship between inflation and the dispersion of relative prices. Unlike earlier literature, the empirical results from this study indicate that inflation per se does not affect the dispersion of relative prices over time. In fact, this dispersion seems to be rising in response to the deviation of inflation from certain threshold level in either direction. The dispersion of relative prices to decline as inflation approaches the threshold level from either direction. The crucial inference that emerges from the empirical evidence is that the inflation rate at which the dispersion of relative prices is minimized turns out to be 4 percent; hence, supporting the proposition of 4 percent inflation target for US and Japan. The rest of the paper is organized as follows: section 2 provides the methodology; section 3 discusses data and empirical results; and section 4 provides the concluding remarks.

THE METHODOLOGY

In the literature, number of studies have examined the divergence among a set of variables by counting the number of significant

cointegrating vectors using Johansen (1991, 1995) cointegration test (see e.g., Mylonidis and Christos, 2010; Rangvid, 2001; Pascual 2003; Siklos and Wohar 1997; and Bernard and Durlauf, 1995). Under this procedure, finding a single common stochastic trend among a vector of n variables i.e., finding the $n-1$ number of significant cointegrating relationships implies larger convergence. On the contrary, as the number of common stochastic trends among the variables increases, the divergence among them tends to increase.³ Thus, an increasing number of significant cointegrating relationships would constitute evidence of decreasing divergence and vice-versa (Rangvid, 2001).

To evaluate the dispersion of relative prices *over time*, we employ Johansen (1991, 1995) cointegration test to a system of component price indices for a sequence of rolling samples. Unlike, the conventional approach of simply comparing the cointegration results obtained from high and low inflation period, the advantage of rolling cointegration test is that it allows to examine the variation in the number of cointegrating relations over time. This approach helps to understand the dynamic relationship between inflation and the dispersion of relative prices in a better manner than the procedure of simply dividing the sample into high and low inflation regime.⁴ More importantly, given the possible sensitivity of cointegration results to sample selection (Hansen and Johansen, 1999; Johansen *et. al.*, 2000), the procedure of dividing the sample period into low and high inflation regime and comparing the cointegrating results may not be appropriate.

In the first stage, we estimated the number of significant cointegrating vectors among component price indices for a sequence of

³ Mylonidis and Christos (2010) demonstrate how decreasing number of cointegrating relationships or increasing number of stochastic trends imply higher divergence among the set of variables.

⁴ Sarno and Valente (2006) provide a detailed discussion on the crucial implications of the variation of parameters over time.

rolling subsamples.⁵ In the second stage, we compare the rank r (number of significant cointegrating vectors) obtained from each rolling sample with the corresponding period average inflation rate. Here, the presence of larger (smaller) number of significant cointegrating vectors (i.e., presence of lesser number of common stochastic trends) implies lesser (wider) dispersion of relative prices over time.

Johansen (1995) demonstrate that the test procedure is unbiased if the rank tests are interpreted as a sequence. Starting from rank zero, the test procedure stops at the first insignificant test statistic. The procedure involves investigation of the k -dimensional vector autoregressive process of p^{th} order:

$$\Delta y_t = \mu + \pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t$$

where Δ is the first-difference lag operator, y_t is a $(k \times 1)$ random vector of k time series variables with order of integration equal to one. μ is a $(k \times 1)$ vector of constants, π is $(k \times k)$ matrix of parameters and ε_t is a sequence of zero-mean k -dimensional white noise vectors. In this framework, the rank (r) of the $(k \times k)$ matrix of π provides information about the long-run relationships among the variables. The rank of π given by $0 < r < k$ implies the existence of r cointegrating vectors among the variables. Thus there exist $(k \times r)$ matrices of α and β , each of rank r such that $\pi = \alpha\beta'$. The testing of hypothesis that the number of cointegrating vectors is at most r

⁵ Before proceeding to Johansen's cointegration test, we first examine whether the time series on each price is integrated of same order. To this end, we employed a battery of unit root tests for each rolling subsample.

(where, $r=1, 2, \dots, k-1$) is conducted by using both the maximum eigenvalue and trace statistics.

DATA AND EMPIRICAL RESULTS

We have used CPI data from US and Japan as used by Scharff (2007) and Shoemsmith (2000) to conduct the empirical analysis. The common feature of both these countries is that they have experienced similar evolution of inflation over time. We used monthly data on ten major component indices of US CPI for the sample spanning from January-1978 to June-2011. These sub price categories include: food away from home, footwear, fruits and vegetables, fuels and utilities, meat poultry fish and eggs, medical care, men's and boys' apparel, private transportation, shelter, and women's and girls' apparel. Similarly, for Japan, we used monthly data on ten major sub price categories of the CPI basket and the sample period ranges from January-1970 to December-2011. The component price indices for Japan include: housing, fuel light and water, furniture and household utensils, cloths and footwear, medical care, transportation and communication, education, reading and recreation, and miscellaneous.

Firstly, for both US and Japan, we calculate the number of significant cointegrating vectors in a system of component price indices for a sequence of rolling sub samples over the overall sample period.⁶ To this end, Johansen's cointegration test was conducted for a sequence of rolling samples having a window size of 100.⁷

Next, to examine the relationship between inflation and the dispersion of relative prices, we compare the number of significant cointegrating relationships obtained from each period with the

⁶ These results from cointegration tests are not presented here.

⁷ The results of the conventional unit root tests confirmed that the time series of all the component price indices (in logarithmic form) follow I(1) process during each rolling subsample.

corresponding period's average inflation rate. In Figure 1, we plot the average number of significant cointegrating vectors (\bar{r}) (the dotted line in the Figure) against the corresponding period average inflation rate ($\bar{\pi}$) (the thick line) over time for US.⁸ Similarly, in case of Japan, the average number of significant cointegrating vectors (\bar{r}) is plotted against the corresponding period average inflation rate ($\bar{\pi}$) over time in Figure 2. It can be clearly seen that for both the countries initially the number of cointegrating vectors increase as inflation falls up to a certain level (4 percent), and subsequently as inflation falls further to lower levels the number of cointegrating vectors start decreasing. In other words, the results suggest that the number of significant cointegrating relations is comparatively less during the periods characterized with very high or very low inflation. These results indicate that the dispersion of relative price *over time* is minimized (i.e., existence of lesser number of common stochastic trends or higher number of r) as inflation stabilizes around 4 percent. A crucial implication of these findings is the presence of a threshold inflation level at which the dispersion of relative prices is minimized.⁹

⁸ As the rolling subsamples overlap, we present the average number of cointegrating vectors measured over consecutive ten windows and the corresponding period average inflation in each Figure.

⁹ It is important to note that a certain proportion of dispersion in relative prices over time may be due to changes in real factors such as real income, preferences, technology, etc., The variability in relative prices due to such factors is crucial for efficient allocation of resources as it reflects signals purely from market and real sector of an economy. In this context, [Becker and Nautz \(2012\)](#) and [Head and Kumar \(2004\)](#) demonstrate that the rate of inflation that minimizes variability of relative prices can serve as a proxy for the threshold inflation rate that minimizes the welfare cost of inflation. Moreover, number of empirical studies provides evidence for US and many other countries that more than half of variability in relative prices is mainly due to inflation. In particular, [Ram \(1994\)](#) and [Rather et. al. \(2014\)](#) demonstrate that the component of relative price variability due to inflation increases as inflation rises.

Figure 1: Average Inflation and number of $\bar{\pi}$ cointegrating vectors (US)

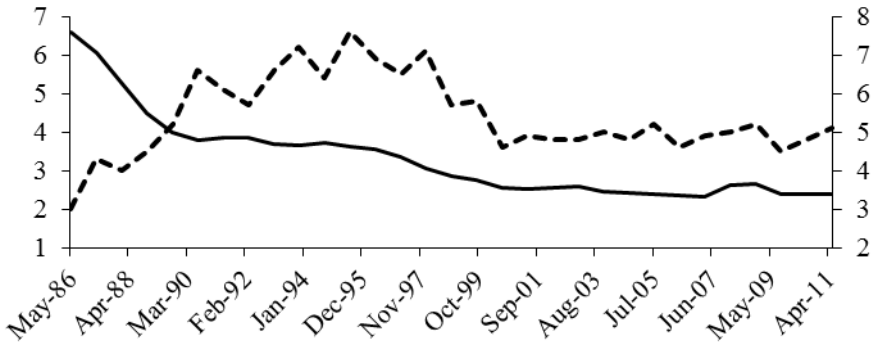
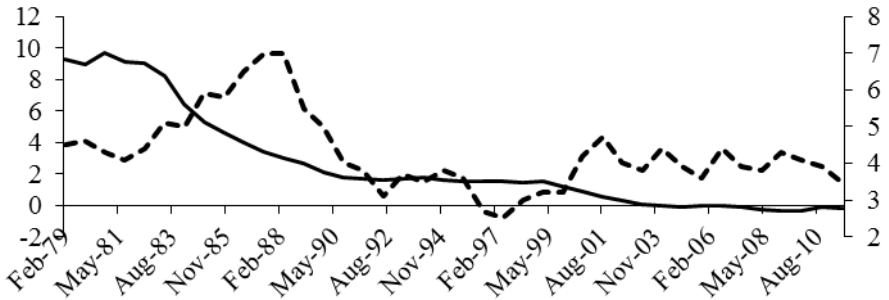


Figure 2: Average Inflation and number of $\bar{\pi}$ cointegrating vectors (Japan)



Source: Authors' estimation.

To trace out this relationship more clearly, we sorted the time series of both inflation and the number of cointegrating vectors with respect to inflation in ascending order. Then based on the results from Figure 1 and 2, we calculated the deviation of inflation from its threshold level $(\bar{\pi} - \pi^*)$ for each period while considering $\pi^* = 4\%$. In Figure 3, we present the scatter plots of average number of significant cointegrating vectors (\bar{r}) against the deviation of average inflation rate

from its threshold level $(\bar{\pi} - \pi^*)$ for US. Here, the vertical axis measures the average number of significant cointegrating vectors (\bar{r}) and the horizontal axis measures the corresponding period's inflation deviation $(\bar{\pi} - \pi^*)$.¹⁰

It is evident from Figure 3 that the number of significant cointegrating relations among component price indices is comparatively lesser when inflation deviates highly from its threshold level in either direction. The number of cointegrating relationships is found to be maximum when the deviation of inflation from its threshold level is zero. These results indicate that the dispersion in relative prices tends to decline as inflation approaches certain threshold level. This finding is consistent with the U-shaped relationship between inflation and relative price variability documented in the recent literature (Fielding and Mizen, 2008; Choi and Kim, 2010; Nautz and Scharff (2012); and Rather *et. al.*, 2014). More importantly, the results support the view that the dispersion of relative prices *over time* changes not with the inflation rate per se as documented by Shoemith (2000) and Scharff (2007), but with the deviation of inflation from its threshold level.

The results for Japan are presented in Figure 4. Similar to what we have observed for US, the scatter plot exhibits an inverted U-shape pattern indicating that there exists less number of cointegrating relations (i.e., more dispersion of relative prices) during periods of very low and very high inflation. In other words, the farther away a shock drives inflation from the π^* in either direction, the more dispersed are relative prices over time. In case of Japan too, the number of cointegrating relations is found to be maximum when deviation of inflation from its threshold level is zero or inflation is around 4 percent. Over all, these evidences suggest that for inflation levels below the threshold level, rise

¹⁰ Expanding the size of rolling window, however, does not significantly alter the results.

in inflation tends to reduce dispersion in relative prices and on the contrary, for inflation levels above the threshold level, an increase in rate of inflation results in larger relative price dispersion.¹¹

Figure 3: Inflation Deviation and Number of Cointegrating Relations (r) for US

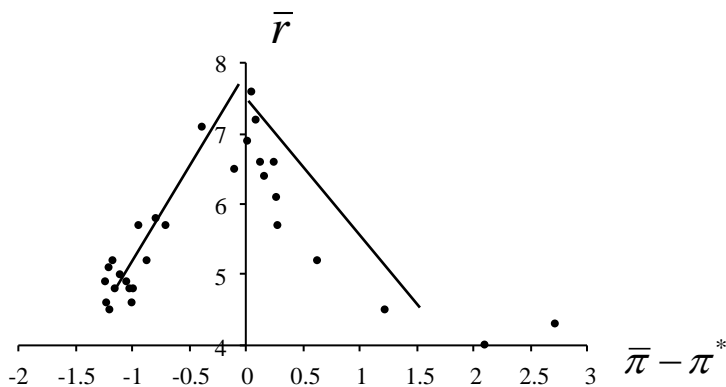
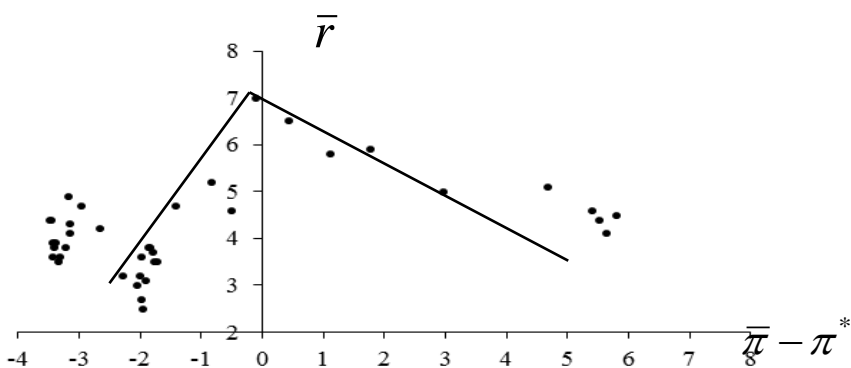


Figure 4: Inflation Deviation and Number of Cointegrating Relations (r) for Japan



Source: Authors' estimation.

¹¹ No significant change in the inferences was found when we used the sample periods considered by Shoesmith (2000) and Scharff (2007).

The striking feature of the empirical evidence is that the dispersion of relative prices *over time* is minimized (existence of maximum number of cointegrating relations) when average inflation is around 4 percent for both US and Japan. Interestingly, this finding substantiates the argument of Blanchard *et. al.* (2010) and Ball (2013) in favor of raising the inflation target to 4 percent. Although their argument is based on the rationale that raising the inflation target would ease the constraints on monetary policy arising from zero bound on interest rate, the target inflation rate they propose is the same as obtained here. On the same line, Krugman (2013) argues that a higher baseline for inflation, say 4 percent, than a conventional target of 2 percent makes liquidity trap less likely to occur and less costly even when it occurs. Hence, stabilizing the inflation around 4 percent will not only minimize the dispersion of relative prices but also ease the constraints/costs arising from zero bound and the liquidity trap.

Overall, the empirical results indicate that the component price indices drift apart considerably as inflation deviates farther away from certain threshold level; implying that both very low and very high inflation generate larger relative price dispersion *over time*. The results further confirm that what matters for the response of relative price dispersion is not the inflation per se as recognized in the earlier literature, but the deviation of inflation from certain threshold level.

CONCLUDING REMARKS

This paper examines the relationship between inflation and the dispersion of relative prices *over time* using the CPI data from US and Japan. To measure the dispersion of relative prices over time, we count the number of significant cointegration relations in a system of component price indices for a sequence of rolling samples. Under this procedure, a lesser number of significant cointegrating vectors (i.e., presence of more

number of common stochastic trends) implies larger dispersion among prices and vice-versa. The empirical results, unlike the earlier studies, indicate that inflation per se does not affect the dispersion of relative prices. In fact, the dispersion of relative prices over time seems to be rising in response to the deviation of inflation from certain threshold level in either direction. In other words, the dispersion of relative prices tends to decline as inflation approaches to the threshold level from either direction. The crucial inference that emerges from the empirical analysis is that the inflation rate at which the relative price dispersion is minimized turned out to be 4 percent for both US and Japan. These findings support the proposition of 4 percent inflation target for both the countries.

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