Relative Price Changes as Supply Shocks: Evidence from U.S. Cities

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This paper estimates a fixed effects regression model using panel data on prices for U.S. cities to test the supply-side theory of inflation that takes the distribution of relative price changes as an aggregate supply shock. The results indicate that the positive correlation between inflation and relative price variability is a robust empirical regularity that gives some credibility to the supply-side theory of inflation. During the early 1980s this relationship, though positive, weakens which indicates predominance of monetary shocks in determining changes in the aggregate price level. On the other hand, inflation and skewness are not found to be strongly related when aggregate macroeconomic effects are controlled.

Introduction

There is a substantial literature that explores the relationship between inflation and the distribution of relative price changes. It is widely documented that there is a positive relationship between inflation and the dispersion of relative price changes. Although somewhat less appreciated, inflation and the skewness of relative price changes also are found to be positively correlated. The theoretical exposition has not been conclusive in regards to the causal mechanism that generates the observed relationships. Theories that have been proposed to explain these relationships fall into one of three categories. The first category of theory shows that the causation runs from inflation to relative price variability (RPV).[1] The second category, on the other hand, takes relative price variability or the skewness of relative price changes as exogenous and shows that inflation is caused by the distribution of relative price

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[1] In most empirical studies, RPV essentially means the dispersion of price changes across commodity groups.

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changes. The third category of theory propounds that both inflation and relative price variability are generated by some exogenous factor. Efforts to test these alternative theories have given rise to a voluminous empirical literature. This paper is an attempt to test the theory—proposed by Ball and Mankiw (1995)—that considers relative price variability/skewness as aggregate supply shocks that drive inflation, using city-level price data for the U.S.

Most empirical work[2] uses price data for the aggregate economy and investigates the relationship between aggregate inflation and the distribution of relative price changes. In recent years, however, there have been at least three studies that use panel data on city-level prices for the United States. (1) Reinsdorf (1994) uses a panel that runs from 1980 to 1982 for 65 commodities in nine U.S. cities. Surprisingly, he finds a negative relationship between inflation and relative price dispersion;[3] (2) David Parsley (1996), on the other hand, finds a positive relationship between inflation and relative price variability using a panel data set that includes quarterly price data for 28 consumption items, collected by the American Chamber of Commerce Researchers Association (ACCRA) for 48 cities in the U.S.; (3) Debelle and Lamont (1997) use CPI data for major U.S. cities to examine the relationship between inflation and relative price variability and find them to be positively related.

In related studies using other forms of spatial data, Lach and Tsiddon (1992) use a panel data set on prices of foodstuff collected from different stores during 1978-1984 in Israel, and Loungani and Swagel (1995) investigate the inflation-price dispersion/skewness relationship using a panel VAR methodology applied to data for 13 OECD countries. Except for the last one, all these studies assume that the causation runs from inflation to relative price variability.

The current study differs from these previous studies in that it assumes that inflation is caused by the distribution of changes in relative prices.[4] In other words, it is intended to test the supply-side theory of inflation that was proposed by Ball and Mankiw (1995). Although different in approach, this paper shares the same spirit as Loungani and Swagel (1995) who evaluate the supply-side theory in a cross-country context. It may be noted that they find supply-side shocks, such as standard deviation and skewness of relative price changes, to be statistically significant determinants of inflation.

The results of this paper indicate that the positive correlation between inflation and the dispersion of relative price changes is a robust empirical regularity that gives

[2] For example, Vining and Elwertowski (1976), Parks (1978) and Fischer (1981)

[3] As Parsley (1996) and Debelle and Lamont (1997) point out, this may be due to the use of data for the early 1980s or the Volcker disinflation years. Moreover, Reinsdorf finds a positive relationship between price dispersion and expected inflation.

[4] Ball and Mankiw (1995) and Balke and Wynne (2000) have estimated similar models using price data for the aggregate economy.

some credence to the supply-side theory of inflation. Inflation and skewness are not found to be strongly correlated, however, when we control for the effects of economy-wide factors.

A Supply-Side Theory of Inflation

The classical theory of inflation rules out any implication of relative price changes—which are believed to be driven by real factors—for aggregate inflation. According to this view, for a given stock of money, increases in some prices are offset by decreases in some other prices. Thus, the aggregate price level is unaltered. The aggregate price level changes only when money supply changes. In other words, according to the classical view, inflation is driven by aggregate demand factors only. During the 1970s high inflation was accompanied by a low level of output, a phenomenon called stagflation. The classical framework did not explain this phenomenon well. On the other hand, this could consistently be explained by changes in aggregate supply conditions. Also, a closer look at the anatomy of inflation during that period reveals that this inflation was mainly driven by changes in relative prices of a few commodities such as oil and food.[5] Thus, the relative price changes had the essential traits of an aggregate supply shock. Economists, however, came up with various different stories to interpret relative price changes as supply shocks.

Ball and Mankiw (1995) exploit the positive relationship between inflation and relative price dispersion/skewness to propose a theory of aggregate inflation in which relative price changes are considered as aggregate supply shocks. They argue that the existence of such relationships is “a novel empirical prediction” of a menu costs model.[6] Because of “menu costs” (the costs of adjusting prices) firms’ responses to shocks are asymmetric: they adjust prices only in response to large shocks. Thus, large shocks have disproportionate effects on the price level and the resultant changes in relative prices have implications for aggregate inflation. If the distribution of desired price changes is skewed to the right, a shock will lead to more increases in relative prices than decreases, and inflation will be higher. On the other hand, when the distribution is skewed to the left, decreases occur more quickly than increases, and inflation is lower. This supply-side theory predicts that the skewness of relative price changes will be correlated with aggregate inflation. This theory further

[5] Writing on the stagflation of the 1970s, Blinder (1982) argues that “the dramatic acceleration of inflation between 1972 and 1974 can be traced mainly to three ‘shocks’: rising food prices, rising energy prices and the end of the Nixon wage-price controls program.” Similarly, he attributes the acceleration of inflation between 1978 and 1980 to food shock, soaring energy prices, and rising mortgage rates.

[6] More recently, Balke and Wynne (2000) have questioned this interpretation and have shown that even with fully flexible prices it is possible to have a positive relationship between inflation and RPV/skewness when price changes are driven by sectoral technology shocks.

suggests that high variability of price changes magnifies the effect of skewness on inflation because a larger variance of shocks leads to more weight in the tails of the distribution. A given skewness shock then leads to an even greater disparity between the number of price increases and decreases.

In order to provide empirical evidence for their theory in the U.S., Ball and Mankiw estimate several regressions with the aggregate inflation as the dependent variable. These regressions include lagged inflation, standard deviation of relative price changes, skewness of price changes, and the interaction of standard deviation and skewness—one at a time, or all of them together—as regressors. They find that standard deviation and skewness of relative price changes have statistically significant positive effects on aggregate inflation.

Data Set and Empirical Method

Data

The city level annual Consumer Price Index (CPI) data were obtained from the U.S. Bureau of Labor Statistics (BLS). These indexes are available on the BLS website (www.bls.gov) for 26 city areas,[7] for major categories of consumer expenditures, and for major items within each category. The data used in the present study are for all urban consumers. Although monthly data are available for a few cities (Chicago, Los Angeles, and New York), the most common frequency is annual. I use two balanced panels of annual CPI data for U.S. cities:[8] the first panel includes price data on seven consumption items in 20 cities[9] for a period from 1967 to 2001. The second panel, on the other hand, includes price data on nine consumption items in 23 cities[10] for a period from 1980 to 2001.[11] The choices of number of cities, number of consumption items, data frequency, and the sample periods for each panel are dictated mainly by the availability of data. The cities and consumption items included in these two panels are described in Appendix Table A.1.

[7] In addition to these 26 major metropolitan areas with population of over 1.5 million in each, the BLS sample includes metropolitan areas with population smaller than 1.5 million and nonmetropolitan areas as well.

[8] The data used in this study can be obtained from the author.

[9] According to the 1999-2000 weights, the combined weights of these seven items (percentage share of total consumption expenditure on these items in a typical urban household's budget) range between 76.1 percent for Minneapolis and 80.6 percent for Atlanta.

[10] The weights, in this case, range between 82.5 percent for Kansas City and 85.8 percent for San Francisco.

[11] The reason for considering the second panel is to verify whether exclusion of the 1970s eliminates or weakens the relationship between inflation and distribution of relative price changes. Although I could have used a truncated panel obtained from the first one, inclusion of more consumption items and cities means more information, which is deemed to be better.

I use these data sets to construct data on the variables required for this study. I first define the following variables. Let $P_{j,t}$ be the consumer price index of all items in city j in year t . Then the inflation in city j in year t is defined as

$$DP_{j,t} = \ln P_{j,t} - \ln P_{j,t-1} \tag{1}$$

Relative price variability (RPV) for city j in year t is defined as

$$VP_{j,t} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(DP_{i,j,t} - \overline{DP}_{j,t}\right)^2} \tag{2}$$

where

$$\overline{DP}_{j,t} = \frac{1}{n}\sum_{i=1}^{n} DP_{i,j,t}$$

is the mean price change (averaged across consumption items) [12] in city j in period t. Also, note that i indexes consumption items and n is the number of items. This variable is essentially the standard deviation of price changes.[13] Skewness of price changes for city j in period t is defined as follows:

$$SP_{j,t} = \frac{1}{(n-1)(n-2)}\sum_{i=1}^{n}\left(\frac{DP_{i,j,t} - \overline{DP}_{j,t}}{VP_{j,t}}\right)^3 \tag{3}$$

Because both inflation and relative price changes at the city level are affected by aggregate macroeconomic factors, in one set of specifications of the regression model I use these variables in deviation form that controls for the effects of such economy-wide factors. Following Debelle and Lamont (1997), I construct data on these variables in deviation form by subtracting the U.S. national inflation, the national RPV and the national skewness measures from the corresponding city level measures for each year. The new variables are defined as follows:

$$\hat{DP}_{j,t} = DP_{j,t} - DP_{US,t} \tag{4}$$

$$\hat{VP}_{j,t} = VP_{j,t} - VP_{US,t} \tag{5}$$

[12] Note that $P_{j,t}$ is constructed as a weighted index of all underlying prices and therefore it is desirable that both $VP_{j,t}$ and $\overline{DP}_{j,t}$ are calculated as weighted standard deviation and mean respectively. As I discuss later, however, the results as far as the relationship between inflation and RPV is concerned are qualitatively not different. Moreover, some prominent studies (e.g., Vining and Elwertowski, 1976, Reinsdorf, 1994, Debelle and Lamont, 1997) use unweighted measures.

[13] Note that other measures of relative price variability have been used in the literature. For example, Parsley (1996) uses four different measures of relative price variability including one of the dispersion of relative prices (not price changes).

$$\hat{SP}_{j,t} = SP_{j,t} - SP_{US,t} \quad (6)$$

where the variables with subscript US,t represent the national level inflation, RPV, and skewness of relative price changes[14] in period t, respectively.

Table 1 presents summary statistics of the variables of interest for the period 1968-2001. For each variable, I first present summary statistics for the case where the aggregate macroeconomic effects have not been controlled, and then I present summary statistics of the variables in deviation form (in which case these aggregate effects have been controlled).

Table 1—Summary Statistics of Inflation, Relative Price Variability, and Skewness of Price Changes 1968-2001

	Mean (1)	Standard Deviation (2)	Minimum (3)	Maximum (4)	Observations (5)
Aggregate Economy (U.S. City Average)					
Inflation	0.049	0.028	0.015	0.127	34
Relative Price Variability	0.022	0.009	0.009	0.042	34
Skewness of Price Changes	-0.058	1.062	-2.166	2.179	34
20 U.S. Cities					
Inflation					
$DP_{j,t}$	0.049	0.029	-0.010	0.156	680
$\hat{DP}_{j,t}$	0.000	0.009	-0.030	0.044	680
Relative Price Variability					
$VP_{j,t}$	0.029	0.012	0.008	0.094	680
$\hat{VP}_{j,t}$	0.007	0.009	-0.015	0.064	680
Skewness of Price Changes					
$SP_{j,t}$	0.037	0.988	-2.465	2.508	680
$\hat{SP}_{j,t}$	0.095	1.066	-3.797	3.189	680

Note: Price changes are calculated by taking first log differences of CPIs. Thus 100 × first log differences indicate percentage changes

[14] These national measures are calculated from the U.S. city average CPIs for all items and for the items in the samples used in this paper. Because the cities in the samples of this paper account for about 50 percent of all urban areas included in the BLS sample according to the 1999-2000 weights, they may be different from averages of these measures across the sample cities.

The following observations can be made from this table. First, when the aggregate macroeconomic effects are controlled, the variability of inflation across cities and time is more than halved, indicating that national factors contribute a great deal to the (across-time) variability of inflation. Second, the relative price variability across commodity groups (denoted by VP) decreases substantially when the macroeconomic effects are controlled, but the variability of VPs across time and across cities does not change much. This suggests that the dispersion of relative price changes that results from economy-wide factors is much larger than the dispersion that emerges from city-specific factors. The effects of these aggregate factors do not vary much across time and cities. Third, when the macroeconomic factors are controlled, the skewness of price changes increases which suggests the importance of city-specific factors in producing large changes in the prices of selected items.

Empirical Approach

As the objective of this paper is to test the supply-side theory of inflation, in the regression model inflation is treated as the dependent variable, and dispersion and skewness of relative price changes are included as independent variables. In order to allow for city-specific and year-specific components of city-level inflation, city dummies and year dummies also are included. When the variables are used in deviation form, however, year dummies are not included. The intuition is that the year dummies capture the aggregate macroeconomic effects[15] for which I already have controlled. Thus, a general fixed effects model is specified as:

$$\hat{DP}_{j,t} = \sum_{j=1}^{m} \lambda_j + \beta_1 \hat{VP}_{j,t} + \beta_2 \hat{SP}_{j,t} + \beta_3 \left(\hat{VP}_{j,t} \times \hat{SP}_{j,t} \right) + u_{j,t} \tag{7}$$

where λs are the city-specific dummies and m is the number of cities. The interaction term is included in order to allow for the possible effect of interaction between RPV and skewness of relative price changes[16] on inflation.

The model also is estimated with variables that are not controlled for the aggregate macroeconomic effects. In these specifications year-specific dummies are included instead in order to control for the effects of macroeconomic factors.[17] The general specification of the model, in this case, is as follows:

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[15] Parsley (1996) includes year dummies in his regression model to control for aggregate macroeconomic factors. Moreover, estimation of the model in deviation form with time dummies renders these dummies statistically insignificant.

[16] Ball and Mankiw (1995) include this interaction term in the estimation of their OLS regression model and find them to have significant positive relation with inflation.

[17] Estimation of a fixed effects regression with variables in deviation form and no time dummy and a fixed effects model with time dummies should give identical coefficient estimates. As explained in an earlier footnote, the national average measures that are subtracted from the city-level measures may be different from the averages of inflation, RPV, and skewness across

$$DP_{j,t} = \sum_{j=1}^{m} \lambda_j + \sum_{t=1}^{T-1} \tau_t + \beta_1 VP_{j,t} + \beta_2 SP_{j,t} + \beta_3 \left(VP_{j,t} \times SP_{j,t} \right) + u_{j,t} \quad (8)$$

where τs are the year dummies and T is the number of years.

Results

Several specifications of the model are estimated. In the first set of specifications, the variables in deviation form are included, and the first panel is used to estimate the models.[18] This set consists of models with following regressors:

Model 1: $\hat{VP}_{j,t}$, City Dummies

Model 2: $\hat{SP}_{j,t}$, City Dummies

Model 3: $\hat{VP}_{j,t}$, $\hat{SP}_{j,t}$, City Dummies

Model 4: $\hat{VP}_{j,t}$, $\hat{SP}_{j,t}$, $\hat{VP}_{j,t} \times \hat{SP}_{j,t}$, City Dummies

The results are reported in Table 2. Estimates of these model specifications unequivocally indicate that relative price variability and inflation are positively associated. For all three specifications where $\hat{VP}_{j,t}$ appears as a regressor, the coefficient estimates are highly statistically significant (all at the 1 percent level). An increase of one standard deviation of RPV leads to about 0.17 percent point[19] increase in inflation in Model 1 and Model 3. Because of the interaction term in Model 4, I have to add 0.058×0.095 (estimated coefficient of the interaction term × mean value of skewness) ≈ 0.006 to 0.173 (estimated coefficient of RPV) to estimate the partial effect of RPV on inflation. Thus, in this case, a one standard deviation increase in RPV raises inflation about 0.16 percent point.

The coefficients on skewness are weakly statistically significant (at the 10 percent level) for the second and the third model specification but not significant for the fourth specification.[20] In all three cases (including Model 4 in which I have to make

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the sample cities that the time dummies capture. Therefore, the coefficient measures may not be exactly the same.

[18] Because stationarity is a major concern in case of time series data, I conduct augmented Dickey-Fuller unit root tests for each of the series for each city. For inflation series, the null hypothesis of unit root is rejected for majority of the cities in the sample. Inflation is found to be trend stationary in most cases. Except for Cincinnati and Cleveland, RPV is found to be mean stationary around a nonzero mean. Skewness, on the other hand, is found to have no unit root for all cities in the samples. Because panel unit root tests such as Im-Pesaran-Shin test (2003) are based on the average of augmented Dickey-Fuller test statistics for individual cross-sectional units, the results from the individual tests indicate rejection of null hypothesis of unit root in panel setting for all series.

[19] This number is obtained by multiplying the standard deviation of RPV (Table 1) by the estimated coefficient (for example, $0.009 \times 0.192 \approx 0.0017$ or 0.17 percent point for Model 1).

[20] Standard errors in Tables 2 and 4 have been adjusted for the loss in degrees of freedom from subtracting national averages.

an adjustment for the interaction term), an increase of one standard deviation of skewness of price changes leads to about 0.11 percent point increase in inflation. The interaction term in Model 4 appears to have significant impact (significant at the 5 percent level) on inflation, thus highlighting the importance of the interaction between RPV and the skewness of relative price changes as aggregate supply shocks.

Table 2—Fixed Effects Regression of City-Level Inflation on Relative Price Variability, Skewness of Price Changes (all in deviation form) and City Dummies, 1968-2001 (Variables are measured in percentages)

	Dependent Variable: Inflation in Deviation Form ($\hat{DP}_{j,t}$)			
	(1)	(2)	(3)	(4)
Relative Price Variability in Deviation Form ($\hat{VP}_{j,t}$)	0.192*** (4.683)		0.189*** (4.610)	0.173*** (4.119)
Skewness of Price Changes in Deviation Form ($\hat{SP}_{j,t}$)		0.001* (1.856)	0.001* (1.703)	0.000 (0.239)
Relative Price Variability in Deviation Form × Skewness of Price Changes in Deviation Form ($\hat{VP}_{j,t} \times \hat{SP}_{j,t}$)				0.058* (1.934)
City Dummies	Yes	Yes	Yes	Yes
Adjusted R - Squared	0.045	0.012	0.048	0.053
Standard Error of Regression	0.009	0.009	0.009	0.009
Number of Observations	680	680	680	680
F_{city}	1.22	1.29	1.21	1.24

Notes: t-statistics are calculated by dividing the estimated coefficients by heteroskedasticity consistent standard errors and are shown in parentheses

*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level

F_{city} is the F-statistic for testing the restriction that the city-specific components are not different across cities

The low explanatory power of the models, reflected in low adjusted R - squared, suggests some important omitted effects. Also, as one can see from the last row of Table 2, the hypothesis that the city-specific factors have no differential effects on inflation across cities cannot be rejected.

The second set of model specifications is similar to the first set, except that now the models include year dummies in order to allow for aggregate macroeconomic effects. The results are reported in Table 3. Again the estimated coefficients of the relative price variability ($\hat{VP}_{j,t}$) are positive and highly statistically significant. In Model 1 and Model 3, an increase of one standard deviation of RPV increases infla-

Table 3—Fixed Effects Regression of City-Level Inflation on Relative Price Variability, Skewness of Price Changes and City and Time Dummies, 1968-2001 (Variables are measured in percentages)

	Dependent Variable: Inflation ($DP_{j,t}$)			
	(1)	(2)	(3)	(4)
Relative Price Variability	0.181***		0.179***	0.149***
	(4.415)		(4.366)	(3.548)
($VP_{j,t}$)				
Skewness of Price Changes		0.001*	0.001	-0.001
		(1.651)	(1.489)	(-1.111)
($SP_{j,t}$)				
Relative Price Variability				0.067**
× Skewness of Relative Price Changes				(2.310)
($VP_{j,t} \times SP_{j,t}$)				
City Dummies	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Adjusted R - Squared	0.976	0.975	0.976	0.976
Standard Error of Regression	0.009	0.009	0.009	0.009
Number of Observations	680	680	680	680
F_{city}	1.23	1.30	1.21	1.26
F_{year}	161.02***	183.53***	157.79***	158.03***
$F_{city\ and\ year}$	102.93***	117.02***	100.87***	101.08***

Notes: t-statistics are calculated by dividing the estimated coefficients by heteroskedasticity consistent standard errors and are shown in parentheses

*** Significant at the 1 percent level

** Significant at the 5 percent level

* Significant at the 10 percent level

F_{city} is the F-statistic for testing the restriction that the city-specific components are not different across cities. F_{year} is the F-statistic for testing the joint significance of year-specific components and $F_{city\ and\ year}$ is the F-statistic for testing the joint significance of city and year-specific components

tion about 0.21 percent point. In Model 4, the estimated partial effect of RPV after the adjustment for the interaction term is 0.151.

In none of these specifications does skewness have a statistically significant effect on inflation. In the fourth model, skewness appears to have a negative effect (though not statistically significant) on inflation. After adjusting for the interaction term, however, the estimated partial effect of skewness on inflation becomes positive (0.00048 approximately) but not statistically significant. As in the previous model, the interaction term has statistically significant positive effect on inflation.

As one can see from the results, the goodness-of-fit measures[21] have improved considerably in comparison to those estimated for the first set of models. That the

[21] The adjusted R - squared measures obtained for the first set of models are comparable to those estimated by Debelle and Lamont (1997) whereas the adjusted R - squared measures obtained for the second set of models are comparable to those estimated by Parsley (1996). My numbers are larger than those of Parsley.

test-statistics for joint significance of year dummies are highly significant indicates the importance of aggregate macroeconomic factors in determining inflation, and may explain why I obtain a better fit of the model.

It is by now widely accepted that the high and extremely volatile inflation of 1970s was driven primarily by the so-called supply shocks. By examining whether the relationship between inflation and relative price changes weakens when the price data for the seventies are excluded from the sample, I test whether the inflation of the 1970s was driven by supply shocks—in this case, by the RPV/skewness of price changes. Various specifications of the model are estimated using the second panel data set. The results from the estimation of the models in deviation form are reported in Table 4. Those from the models with variables that are not controlled for the aggregate factors are presented in Table 5.

Table 4—Fixed Effects Regression of City-Level Inflation on Relative Price Variability, Skewness of Price Changes (all in deviation form) and City Dummies, 1981-2001 (Variables are measured in percentages)

	Dependent Variable: Inflation in Deviation Form ($\hat{DP}_{j,t}$)			
	(1)	(2)	(3)	(4)
Relative Price Variability ($\hat{VP}_{j,t}$)	0.069 (1.235)		0.063 (1.235)	0.064 (1.231)
Skewness of Price Changes ($\hat{SP}_{j,t}$)		0.001* (1.920)	0.001* (1.761)	0.000 (0.627)
Relative Price Variability× Skewness of Price Changes ($\hat{VP}_{j,t} \times \hat{SP}_{j,t}$)				0.039 (1.300)
City Dummies	Yes	Yes	Yes	Yes
Adjusted R - Squared	0.057	0.059	0.061	0.061
Standard Error of Regression	0.009	0.009	0.009	0.009
Number of Observations	483	483	483	483
F_{city}	2.23***	2.35***	2.28***	2.30***

Notes: t-statistics are calculated by dividing the estimated coefficients by heteroskedasticity consistent standard errors and are shown in parentheses

*** Significant at the 1 percent level

** Significant at the 5 percent level

* Significant at the 10 percent level

F_{city} is the F-statistic for testing the restriction that the city-specific components are not different across cities

As one can see from the first row of Table 4, the estimated coefficients of VPs, though positive, are much smaller than the ones estimated using the first panel and reported in Table 2. Also, in terms of statistical significance these relationships are much weaker. This may be due to the inclusion of the Volcker disinflation years of early 1980s.[22] This indicates the predominance of the aggregate factors such as the Fed's monetary tightening over supply shocks in determining changes in the aggregate price level.

When the models are estimated with variables that are not controlled for aggregate effects, RPV is found not to be a statistically significant determinant of inflation (Table 5), and the estimated coefficients are comparable to those reported in Table 4. The estimated coefficients of skewness are, though small in magnitude, highly statistically significant. On the other hand, the aggregate factors captured by the year dummies have significant impact on inflation. Also, city-specific factors are found to have statistically significant effects on city level inflation during the 1980s and the 1990s.

The use of unweighted measures of RPV and skewness may be questioned, given the potential for large movements in relatively unimportant consumption items to influence the results. Therefore, the models are re-estimated using weighted measures.[23] The results for the specifications of the model that use variables in deviation form are presented in the Appendix Tables A.2 and A.3.

As one can see from Table A.2, the estimated coefficients of RPV are positive and highly statistically significant. Interestingly, the estimated coefficients are statistically significant, though only at the 10 percent level, even for the second panel that covers the decades of 1980s and 1990s (Table A.3). The magnitudes of these coefficients (in absolute values) are higher than the ones for the unweighted measures. The most interesting result of this experiment is that the estimated coefficients of skewness are negative, though small, for all model specifications and are statistically

[22] In the first panel, the sample period is much longer. Even though the price data for these unusual years are included in the sample, they do not have significant impact on the positive relationship between inflation and RPV.

[23] These weighted measures are calculated as in Parks (1976). Thus, weighted inflation in city j is defined as:

$$DP^{W}_{j,t} = \sum_{i=1}^{n} w_{i,j} DP_{i,j,t}$$

weighted RPV is defined as:

$$VP^{W}_{j,t} = \sqrt{\sum_{i=1}^{n} w_{i,j}\left(DP_{i,j,t} - DP^{W}_{j,t}\right)^2}$$

and weighted skewness is defined as:

$$SP^{W}_{j,t} = \sum_{i=1}^{n} w_{i,j}\left(\frac{DP_{i,j,t} - DP^{W}_{j,t}}{VP^{W}_{j,t}}\right)^3$$

where $w_{i,j}$ is the relative weight of item i in city j and

$$\sum_{i=1}^{n} w_{i,j} = 1 .$$

The 1999-2000 weights for the sample consumption items are obtained from the BLS webpage, and rescaled to use in the calculation of the weighted measures.

significant. Because the effects of macroeconomic factors have been controlled, this may reflect the shape of the distribution of relative price changes that results from city-specific factors associated with a few relatively more important items such as shelter. Nevertheless, the results indicate the robustness of the positive relationship between inflation and RPV.

Table 5—Fixed Effects Regression of City-Level Inflation on Relative Price Variability, Skewness of Price Changes and City and Time Dummies, 1981-2001 (Variables are measured in percentages)

	Dependent Variable: Inflation ($DP_{j,t}$)			
	(1)	(2)	(3)	(4)
Relative Price Variability	0.073		0.069	0.050
	(1.490)		(1.418)	(1.000)
($VP_{j,t}$)				
Skewness of price changes		0.001***	0.001***	-0.001
		(2.992)	(2.899)	(-1.000)
($SP_{j,t}$)				
Relative Price Variability × Skewness of Price Changes				0.074*
				(2.114)
($VP_{j,t} \times SP_{j,t}$)				
City Dummies	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Adjusted R - Squared	0.951	0.951	0.951	0.952
Standard Error of Regression	0.009	0.009	0.009	0.009
Number of Observations	483	483	483	483
F_{city}	2.19***	2.37***	2.29***	2.39***
F_{year}	81.39***	81.08***	77.02***	75.73***
$F_{city\ and\ year}$	39.86***	40.09***	38.02***	37.50***

Notes: t-statistics are calculated by dividing the estimated coefficients by heteroskedasticity consistent standard errors and are shown in parentheses
*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level
F_{city} is the F-statistic for testing the restriction that the city-specific components are not different across cities. F_{year} is the F-statistic for testing the joint significance of year-specific components and $F_{city\ and\ year}$ is the F-statistic for testing the joint significance of city and year-specific components

From the above results, the following conclusions can be drawn. First, the positive relationship between inflation and relative price variability is a robust empirical regularity. In terms of statistical significance, this relationship weakens during the early 1980s.[24] Second, when unweighted measures of the variables are used, skew-

[24] I estimate the model excluding the years of Volcker disinflation from the sample and find that the estimated coefficients of relative price variability are statistically significant. I have not reported the results here.

ness of relative price changes has a weak but mostly positive relationship with inflation. For weighted measures, skewness has a statistically significant, though small in magnitude, negative relationship with inflation. Thus, the evidence in the city-level price data in support of the supply-side theory of inflation is mixed. Third, when the model is estimated with variables in deviation form, the adjusted R - squared are small, which indicates important omitted variables.

Concluding Remarks

This paper tests the supply-side theory of inflation proposed by Ball and Mankiw using price data for U.S. cities. The results indicate that the positive correlation between inflation and the dispersion of relative price changes is a robust empirical regularity that gives credence to the supply-side theory of inflation. During the early 1980s this relationship weakens, indicating predominance of monetary shocks in determining changes in the aggregate price level. On the other hand, inflation and skewness are not found to be strongly correlated when the effects of the economy-wide factors are controlled. Furthermore, there is significant evidence of a negative relationship when weighted measures are used.

An extension of the current research will be to estimate a panel VAR model. The advantage of the VAR model is that *a priori* one does not have to assume whether the causation runs from inflation to the distribution of relative price changes or from the distribution of relative price changes to inflation. Furthermore, if the results establish that inflation is driven by changes in relative prices that will provide much stronger evidence in support of the supply-side theory. Also, a VAR specification will allow inclusion of lagged variables as regressors. Loungani and Swagel have used the panel VAR methodology to establish the relationship between inflation and RPV/skewness in a cross-country context. They estimate the model using OLS. It is well-known that in a dynamic panel data model, OLS estimates are biased, and it is more appropriate to use IV estimators. The small number of cities as compared to the number of years in the panels used in this paper poses an identification problem. Future research will attempt to find ways to handle such problems.

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Appendix Tables

Table A.1—Description of the Two Panels

Panel 1 (1967 -2001)	
Cities	Atlanta, Boston, Chicago, Cincinnati, Cleveland, Dallas, Detroit, Honolulu, Houston, Kansas City, Los Angeles, Milwaukee, Minneapolis, New York, Philadelphia, Pittsburgh, San Diego, San Francisco, Seattle, St. Louis
Expenditure Categories	Apparel, Food at home, Food away from home, Shelter, Fuels and utilities, Medical care, Transportation
Panel 2 (1980 -2001)	
Cities	Anchorage, Atlanta, Boston, Chicago, Cincinnati, Cleveland, Dallas, Detroit, Honolulu, Houston, Kansas City, Los Angeles, Miami, Milwaukee, Minneapolis, New York, Philadelphia, Pittsburgh, Portland, San Diego, San Francisco, Seattle, St. Louis
Expenditure Categories	Apparel, Food at home, Food away from home, Alcoholic beverages, Shelter, Fuels and utilities, Household furnishings, Medical care, Transportation

Table A.2—Fixed Effects Regression of City-Level Weighted Inflation on Weighted Relative Price Variability, Weighted Skewness of Price Changes (all in deviation form) and City Dummies, 1968-2001 (Variables are measured in percentages)

	Dependent Variable: Weighted Inflation in Deviation Form ($\hat{DP}^{W}_{j,t}$)			
	(1)	(2)	(3)	(4)
Weighted Relative Price Variability in Deviation Form ($\hat{VP}^{W}_{j,t}$)	0.486*** (7.364)		0.490*** (7.538)	0.492*** (7.130)
Weighted Skewness of Price Changes in Deviation Form ($\hat{SP}^{W}_{j,t}$)		-0.002*** (4.411)	-0.002*** (-4.640)	-0.002*** (-4.876)
Weighted Relative Price Variability in Deviation Form × Weighted Skewness of Price Changes in Deviation Form ($\hat{VP}^{W}_{j,t} \times \hat{SP}^{W}_{j,t}$)				-0.006* (-0.136)
City Dummies	Yes	Yes	Yes	Yes
Adjusted R - Squared	0.119	0.046	0.151	0.149
Standard Error of Regression	0.011	0.011	0.011	0.011
Number of Observations	680	680	680	680
F_{city}	1.87**	1.53*	1.65**	1.64**

Notes: t-statistics are calculated by dividing the estimated coefficients by heteroskedasticity consistent standard errors and are shown in parentheses

*** Significant at the 1 percent level

** Significant at the 5 percent level

* Significant at the 10 percent level

F_{city} is the F-statistic for testing the restriction that the city-specific components are not different across cities

Table A.3—Fixed Effects Regression of City-Level Weighted Inflation on Weighted Relative Price Variability, Weighted Skewness of Price Changes (all in deviation form) and City Dummies, 1981-2001 (Variables are measured in percentages)

	Dependent Variable: Weighted Inflation in Deviation Form ($\hat{DP}^{W}_{j,t}$)			
	(1)	(2)	(3)	(4)
Weighted Relative Price Variability ($\hat{VP}^{W}_{j,t}$)	0.238* (1.904)		0.233* (1.926)	0.259** (2.313)
Weighted Skewness of Price Changes ($\hat{SP}^{W}_{j,t}$)		-0.002*** (-4.174)	-0.002*** (-4.224)	-0.000 (-0.559)
Weighted Relative Price Variability × Weighted Skewness of Price Changes ($\hat{VP}^{W}_{j,t} \times \hat{SP}^{W}_{j,t}$)				- 0.171** (2.478)
City Dummies	Yes	Yes	Yes	Yes
Adjusted R - Squared	0.080	0.095	0.115	0.137
Standard Error of Regression	0.010	0.010	0.010	0.010
Number of Observations	483	483	483	483
F_{city}	2.45***	2.19***	2.28***	2.39***

Notes: t-statistics are calculated by dividing the estimated coefficients by heteroskedasticity consistent standard errors and are shown in parentheses

*** Significant at the 1 percent level

** Significant at the 5 percent level

* Significant at the 10 percent level

F_{city} is the F-statistic for testing the restriction that the city-specific components are not different across cities