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Price Variability Under Price Level Stability—A Study of Sierra Leone's Price Dynamics Using Micro-Level Price Data

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This paper offers a unique insight into price dynamics and pricing behavior in Sierra Leone. It examines micro-level price data during a period when the price level remained constant while relative prices displayed considerable volatility. We find that the key factors to explain differences in the average frequency of price changes are inflation volatility and product diversification. Inflation inertia is not significant empirically, except during an earlier period. We show that the variability of relative prices is largely due to a few items that are weighted heavily in the consumer price index. The empirical evidence further suggests that producers in Sierra Leone are more likely to adjust their prices in response to events rather than at fixed intervals. Inflation volatility has also weakened monetary policy effectiveness in Sierra Leone, which could be remedied by introducing a core inflation measure that would exclude volatile product prices.
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This study offers a unique opportunity to analyze disaggregated pricing behavior at the retail level in a developing country.[1] In this study, we utilize micro-level commodity price data for Sierra Leone, which, unlike the

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[1]Virtually all empirical studies on pricing behavior are conducted on advanced economies.

aggregated consumer price data, comprises unindexed price data for all items included in the official consumer price index. Furthermore, the data cover a period of 3½ years during which the overall price level changed relatively little, but relative prices changed frequently.

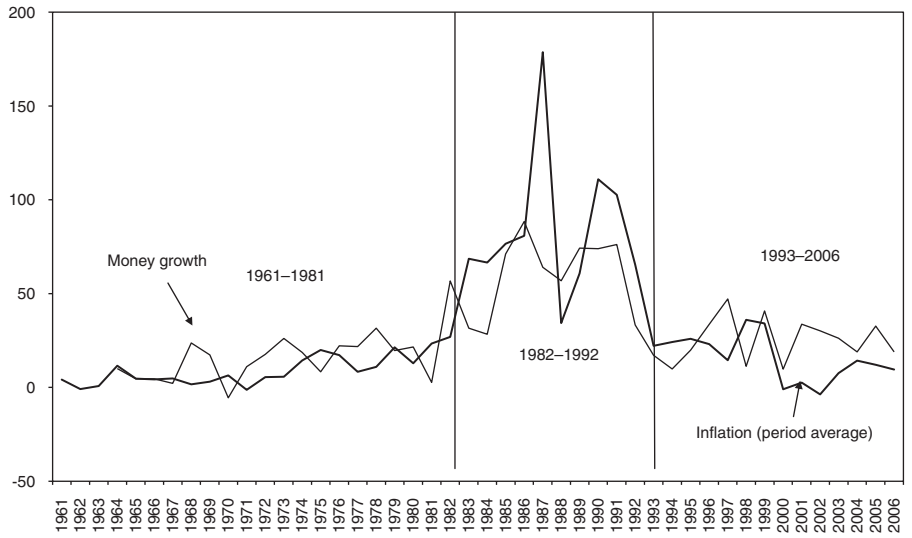
One of the questions we pose is why prices in Sierra Leone change so frequently. We analyze this question using micro-level, cross-sectional data. We show that the different frequencies with which retailers change prices may be explained by two variables: inflation volatility and the extent to which an item is processed (that is, has a high value added). Uncertainty about future inflation, as measured by inflation volatility, helps explain why retailers change their prices frequently. In an environment where future inflation is subject to uncertainty, enterprises have to be responsive to economic conditions in their pricing decisions. Their ability to absorb costs is also important. Food items, such as rice, are typically unprocessed and comprise mainly the cost of growing the item and the costs of distribution (labor and transportation) and storage. Changes in these costs are likely to be passed on to customers quickly because retailers wish to avoid pricing their products below their marginal costs. For services and products that are processed, it may be easier for retailers to absorb some of the increases in the production costs, at least in the short run, while avoiding adjusting the retail prices frequently. Therefore, the prices of these items are usually changed less frequently.

Furthermore, we analyze price dynamics over time and we model price inertia (persistency) as a function of entrepreneurs' pricing behavior. The key contribution of this analysis is that we are able to show that estimated inertia in Sierra Leone is not a significant factor in explaining price dynamics, because the entrepreneurs tend to utilize state-dependent pricing rules rather than time-dependent pricing rules. However, volatility of inflation in Sierra Leone is an important factor and is shown to be driven, by and large, by the volatility of a few product prices that have significant expenditure weights in the consumer price index. One of them is rice, which is a key staple, and hence volatility in the price of rice, both local and imported, will critically affect the welfare of the population, in particular the poor. The volatility of inflation is also important for the policy authorities. To address the issue, we suggest that a narrower inflation measure be adopted for monetary policy purposes in Sierra Leone.

I. A Perspective on Price Dynamics in Sierra Leone

Sierra Leone is a small, open economy in West Africa. It has a rich resource base as well as a diversified agricultural sector. Its exports are dominated by diamonds but also include some agricultural crops such as coffee and cocoa. However, the long civil conflict created havoc in the infrastructure and economic institutions, undermining the social conditions, and resulted in widespread poverty. The signing of a peace accord in July 1999 in Lomé and the cessation of hostilities were followed by a concentrated effort to resettle the displaced population, which has facilitated the normalization of

Figure 1. Annual Inflation and Money Growth, 1961–2006
(Percent a year)



Sources: Sierra Leonean authorities and IMF staff estimates.

economic conditions. They have reinforced confidence in the economy and contributed to macroeconomic stability. Inflation has fallen to more moderate levels.

The structure of Sierra Leone's economy is rather basic. Retail markets in the country are dominated by small-scale enterprises and individual sellers who offer mainly primary goods for sale. Furthermore, reflecting the structure of consumption and low-income levels, more than one-half of the products included in the consumer basket are food items. The prices of food products, by their very nature, are typically more volatile than the prices of nonfood items, which in part explains the high frequency of price changes in the retail sector.

High inflation episodes have been rare (Figure 1). Annual inflation has averaged less than 25 percent since the country's independence in 1961 and was below 10 percent in the first 18 years after 1961. However, there have been periods in Sierra Leone's history during which inflationary pressures have flared up. In particular, after that rather long period of moderate inflation (1961–81), averaging less than 10 percent per year, inflation rose to almost 200 percent per year in 1987 and was "very high" during 1990–91 (the term "very high" is borrowed from Fischer, Sahay, and Végh (2002), indicating that the annual inflation rate is above 100 percent). High inflation episodes in Sierra Leone have been short, ranging from two to four years, as inflation came down quickly after it had peaked. These patterns are similar to those observed in other high-inflation countries (see, for instance, Fischer, Sahay, and Végh, 2002). Since 1993, inflation has generally been moderate and falling, and its volatility has also declined.

Table 1. Estimates of Inflation Inertia, 1961–2006

(Dependent variable is annual average inflation)[1]

	Full sample		1961–81		1982–92		1993–2006	
	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error
(Without money in the estimation)								
Constant	0.06	0.04	0.03	0.02*	0.52	0.27	0.08	0.04*
π $(t-1)$	0.73	0.26**	0.65	0.19**	0.08	0.56	0.35	0.20
Sigma		0.16		0.56		0.23		0.10
R^2		0.55		0.34		0.01		0.22
F-test (significance)		0.00**		0.01**		0.80		0.09
Durbin-Watson		2.28		2.06		2.22		1.70
(With money in the estimation)								
Constant	−0.07	0.04	0.00	0.02	0.20	0.24	0.16	0.08
π $(t-1)$	0.25	0.31	0.55	0.25*	−0.27	0.48	0.35	0.20
Δm (t)	0.44	0.17**	−0.13	0.13	0.26	0.42	−0.08	0.22
Δm $(t-1)$	0.56	0.24*	0.44	0.12**	0.90	0.43*	−0.28	0.47
Sigma		0.13		0.04		0.18		0.10
R^2		0.71		0.65		0.50		0.27
F-test (significance)		0.00**		0.00**		0.16		0.35
Durbin-Watson		2.11		2.10		2.47		1.42
Memorandum items **(mean and standard deviation)**								
Inflation	23.80	36.23	8.51	7.31	79.31	41.26	15.82	12.31
Monetary growth	29.40	22.88	14.33	10.00	59.53	20.37	24.98	11.76

Sources: Sierra Leonean authorities and IMF staff estimates.

Notes: * indicates statistical significance at 5 percent level; ** indicates statistical significance at 1 percent level.

[1]Standard errors are heteroscedastic consistent.

Historically, as the results in Table 1 suggest, inertia was significant only when inflation and its volatility were low. That is, the estimated inflation inertia (the coefficient of the first-order autoregressive term) was significant during 1961–81, but lost its significance during 1982–92 when inflation rose and became highly unstable. During this period, money growth was an important driver of inflation (Figure 1).

The trend decline in inflation during 1993–2006 produced no significant increase in inflation inertia, and the fit of the equation is poor. This may be because the fall in inflation during the period was associated with relatively high inflation volatility. Money growth was also rapid. Therefore, the interval between successive price adjustments may have become shorter than in the earlier periods.

II. Data and Stylized Facts

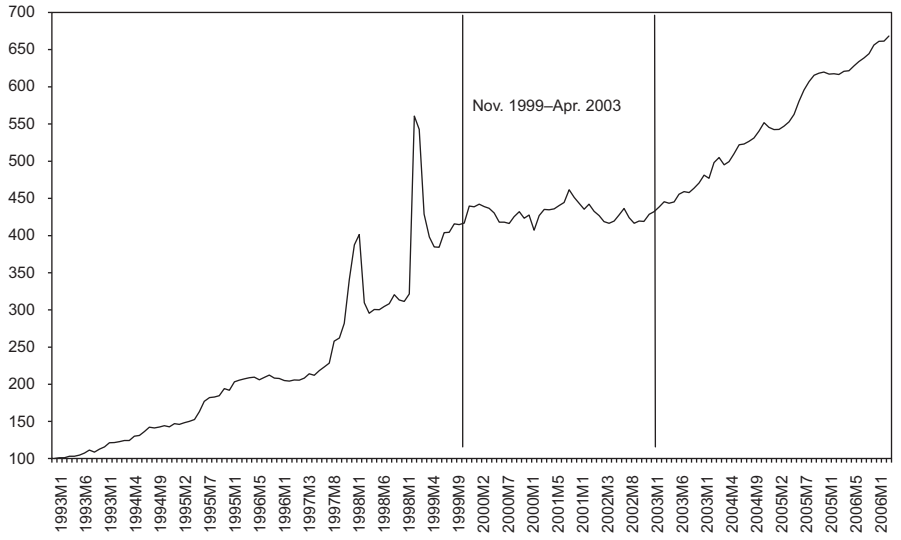
We analyze in this paper a unique consumer price data set comprising average monthly retail prices (unindexed) for all 251 items in the official consumer price index of Sierra Leone. The data were collected by Statistical Sierra Leone and cover the period from November 1999 to April 2003. The consumer price index that is published monthly is based on this data set. In Sierra Leone, the official price index covers only the capital, Freetown (a number of regional indexes are produced for other larger cities). The consumer goods are allocated in 13 groups reflecting various expenditure categories. For each item, a monthly retail price is derived as a simple average of surveyed prices for a fixed number of producers at different collection points in Freetown during each month.[2] Food items represent about 60 percent of the index and include food, drinks, and tobacco. Because we only have information about the average surveyed prices, the data prevent us from measuring directly how frequently and by how much individual retailers changed their prices each period. What makes the period under study unusual is that the price level changed relatively little (Figure 2).

The estimated frequency of price changes (based on average change in the reported monthly price for each product) ranges from zero for four items[3] whose prices were unchanged during the sample period, to almost one for 41 items whose prices were changed virtually monthly (Figure 3). The estimated median frequency is about one-third, which means that the average price of a typical item in the consumer basket is adjusted once every three months during the three-and-a-half-year period under study. Almost all items whose prices changed frequently were food products, but this category also included some nonfood items (soap and firewood). The median length of time that prices remain unchanged in Sierra Leone is considerably shorter than, for instance, in the U.S. markets (Bils and Klenow, 2004).

[2]However, data on four types of rent rates are collected quarterly.

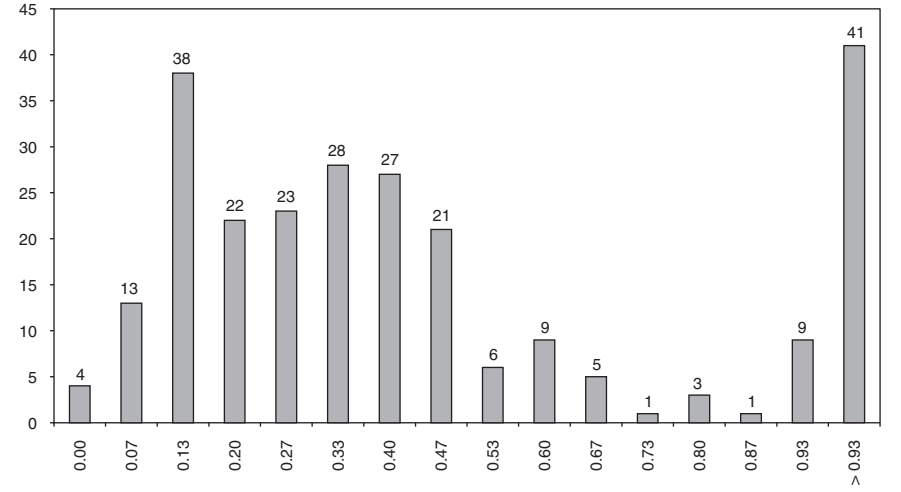
[3]These were subsidized housing rents; rental value of rent-free housing; charges for utilities and repairs; and the price of matches.

Figure 2. Price Level January 1993–December 2006
(Index number; January 1993=100)



Sources: Sierra Leonean authorities and IMF staff estimates.

Figure 3. Average Monthly Frequency of Price Change by Product, 1999M12–2003M4
(Height indicates the number of items included in each frequency)



Sources: Sierra Leonean authorities and IMF staff estimates.

Other stylized facts may be summarized as follows:

- The prices of food items were adjusted, on average, more or less every month, whereas rents and charges for various utilities, and the price of

transportation and communication were adjusted infrequently. One reason for more frequent price changes in the food category is that food items are usually unprocessed and have little value added beyond their primary input costs to absorb cost shocks.

- Many items whose prices were adjusted less frequently could be subject to administrative pricing, including rental rates, the cost of transportation and communication, and fees for medicines and medical care and education.
- Average monthly price changes vary substantially across expenditure groups.
- The increased availability of goods and services in Sierra Leone, following improvements in economic and political conditions, improved supply of agricultural products from local farmers after the end of the civil conflict, and increased imports has improved supplies and dampened costs, putting downward pressure on many prices.[4] Therefore, the prices of certain goods and services fell during the sample period because of positive supply shocks.
- Although inflation was little changed during the sample period, individual prices displayed considerable volatility. The prices of food items in general, and the prices of drinks and tobacco in particular, displayed significant volatility.

III. Related Literature

Empirical research using micro-level pricing data has grown rapidly in recent years, in part because of the need to better understand the causes of price rigidities in an economy. Studies in the area have generally focused on industrial countries. Below we highlight some main conclusions from this literature, which helps put the results for Sierra Leone into perspective.

One of the key issues is whether enterprises follow time- or state-dependent pricing models. In time-dependent pricing models, based on Taylor (1980) and Calvo (1983), enterprises adjust their prices on the basis of a time-contingent pricing mechanism. An important implication of the model is that the fraction of prices changing each period is determined exogenously and remains constant over time. In state-dependent pricing models, on the other hand, enterprises choose when to change their prices subject to ''menu costs,'' rather than adjust their prices at fixed intervals. That is, they adjust their prices in response to specific events (Dotsey, King, and Wolman, 1999). Because of the explicit cost associated with price change, it will be profitable for an enterprise to change its price only if the increment to profits from reoptimization of the price covers the cost of making the change.

[4]This is highly probable for items in the categories of personal goods and services, clothing and footwear, and furniture and nonexpendables.

Studies using data for European countries and the United States offer similar results. Klenow and Kryvtsov (2005) show that pricing behavior in the United States is consistent with the assumptions of time-dependent pricing models. Bils and Klenow (2004) further show that consumer prices in the United States changed relatively frequently—about half of the prices remained unchanged for less than 4.3 months. However, these were greatly different across sectors. For Europe, Dias, Dias, and Neves (2004) find, as in the United States, that the prices of food items changed more frequently than the prices of nonfood items in Portugal. These items are typically unprocessed. Furthermore, the prices of goods were adjusted more frequently than those of services. They also report that higher inflation prompted enterprises to adjust their prices more frequently than during periods of lower inflation. Fabiani, Gattulli, and Sabbatini (2004) find that the bulk of Italian firms used both time- and state-dependent pricing strategies (see Hall, Walsh, and Yates, 2000; Apel, Friberg, and Hallsten, 2001; and Aucremanne and Druant, 2005).

Levy, Dutta, and Bergen (2002) examine the heterogeneity of price rigidity in the United States using retail, wholesale, and spot prices for 12 orange juice producers and find that prices were more rigid in response to small changes in cost shocks than to large shocks, and more rigid in response to temporary than to permanent cost shocks. The authors conclude that firms were more likely to absorb temporary cost increases, possibly because of concern over losing customers, which contributed to price rigidities at the retail level. Prices were also more rigid when producers had less information about the cost shocks. These findings are consistent with the menu-cost models. Restaurant prices in the United States were adjusted less frequently than the prices of other consumer goods (MacDonald and Aaronson, 2000). Carvalho (2006) underscores that heterogeneity is important for price-setting behavior and shows that in these models monetary shocks have larger and more persistent real effects compared with the identical-firm sticky-price models.

A key conclusion emerging from the literature on relative prices is that inflation and relative price variability are positively correlated (see Parks, 1978; Hercowitz, 1981; Fischer, 1982; Parsley, 1996; and, more recently, Nautz and Scharff, 2005). Relative price effects can also persist (Fielding and Mizen (2000) for some European countries, and Debelle and Lamont (1997) for selected U.S. cities). Several studies have found a strong correlation between the rate of inflation and the skewness of the relative price distribution (for example, Vining and Elwertowski, 1976; and Ball and Mankiw, 1995). Furthermore, Bryan and Cecchetti (1996) argue that the mean-skewness correlation could be caused by small sample bias, which was more significant when the distribution had fat tails. Balke and Wynne (2000) suggest that the positive mean-skewness correlation could arise as a result of technology shocks even if prices are flexible. Suvanto and Hukkinen (2004) show that price stability in Finland was associated with significant relative price adjustments.

IV. What Explains Price Volatility in Cross-Sectional Data?

We have provided evidence to suggest that commodity prices in Sierra Leone are volatile and are adjusted frequently. Table 2 shows that the frequency of monthly price change in the cross-sectional data is positively correlated with the level of inflation and inflation variability (measured by the standard deviation of monthly inflation). Furthermore, monthly inflation is almost perfectly correlated with inflation variability (one should note that the results are not suggestive of the direction of causality).

For nonfood items, the frequency of price changes is negatively correlated with inflation and with the variability of inflation. A negative correlation for nonfood items could be explained by administrative pricing in several expenditure categories (rents, rates, and repair; medicine and medical care; transportation; and education). While price changes have been infrequent, individual price adjustments may have been sizable.

In Sierra Leone, the data suggest that uncertainty about the economic and political conditions could be important for pricing decisions, which then translates into higher inflation volatility. Therefore, entrepreneurs increase the frequency of price adjustments in order to protect them from unexpected shocks such as interruptions in supplies and changes in aggregate demand.

To test this, we estimate a panel regression for the average frequency of price change using a constant, a variable for inflation uncertainty (standard deviation of monthly inflation), and a dummy for ''nonprocessed'' goods as explanatory variables.[5] Estimation results are reported in Table 3.

In Table 3, the constant term could be interpreted as the unweighted average frequency of price change in the sample (the estimated average interval between price changes is about three months). The variable measuring inflation uncertainty is statistically significant in the estimation, suggesting that higher inflation uncertainty increases the frequency of average price adjustments. Monthly inflation was statistically insignificant in the estimation, which may be because enterprises' responses to inflation uncertainty are probably nonlinear and hence inflation variability is a better proxy for it. The dummy for nonprocessed items was highly significant in the estimation, supporting the argument that the retail prices of less diversified items are adjusted on average more frequently.

V. An Illustrative Model of Price-Setting Behavior

As we mentioned in Section II, an important limitation in the data used for this paper is that we have information about only the average monthly price for each item included in the consumer price index, which does not allow us to analyze directly entrepreneurs' pricing behavior. Therefore, for us to make inference about (unobserved) entrepreneurs' pricing behavior, we introduce a

[5]Almost all nonprocessed goods, defined as those with relatively low value-added content, are food items.

Table 2. Correlation in Cross-Sectional Data

	Inflation	Frequency	Variability
Inflation	1.0		
Frequency	0.3	1.0	
Variability	0.9	0.3	1.0

Sources: Sierra Leonean authorities and IMF staff estimates.

Table 3. Average Frequency of Monthly Price Changes[1]

	Estimate	SE	*T*-Value	H.C.S.E.	*T*-Value
Constant	0.24	0.02	10.39**	0.02	10.13**
St. Dev. (π)/100	0.57	0.15	3.85**	0.19	2.96**
Dummy[2]	0.50	0.04	13.38**	0.04	12.50**
R^2		0.52			
Residual sum of squares		11.96			
F(2, 242)		130.70**			
Sigma		0.22			
Normality test	$\chi^2(2)$	25.27**			
Heteroscedasticity test	F(3, 238)	1.34			
Reset test	F(1,241)	0.01			

Source: IMF staff estimates.

Notes: ** indicates statistical significance at 1 percent level. SE stands for standard error, and H.C.S.E. refers to the heteroscedasticity consistent standard errors. *T*-statistic values are calculated as the ratio of parameter estimate and its standard error. Items whose prices did not change during the period under study were excluded.

[1]The dependent variable measures the average frequency of price change.

[2]Dummy variable: "1" for nonprocessed goods and "0" for others.

model that will capture the underlying pricing behavior at a more aggregated level.

The simple model, which we develop below, will help us illustrate factors that influence inflation dynamics in an economy, including how changes in commodity prices are linked to firms' pricing behavior. The results will be important when we examine the consumer price data for Sierra Leone.

We use the model by Ball and Romer (1989), but expand it to allow heterogeneity in entrepreneurs' pricing behavior. We also derive specific functional forms for the price level and individual product prices, which allow us to distinguish between economy-wide and product-specific inertia in price dynamics (see Carvalho, 2006) and highlight the presence of spillovers from the aggregate economy to individual product prices.

The economy produces and consumes a large number of differentiated products (the total number of products, indexed by j, is N). Each commodity is produced by a large number of identical, monopolistically competitive firms that differ only to the extent of price-setting behavior. They use labor as the only input. The entrepreneurs consume all N products and purchase the $N-1$ products at given prices (they act as price-takers).

The utility function of a representative firm i (producing one of N products, indexed by $i=1,2,\ldots,k$) is defined in terms of its total consumption, $C_i(t)$, and its labor supply, $L_i(t)$.

$$U_i(t) = C_i(t) - \left[\frac{\varepsilon - 1}{\gamma\varepsilon}\right] L_i^{\gamma}(t),$$

$$C_i(t) = \left[\sum_{j=1}^{N} C_{ij}(t)^{(\varepsilon-1)/\varepsilon}\right]^{\varepsilon/(\varepsilon-1)}, \tag{1}$$

where $C_{ij}(t)$ is entrepreneur i's consumption of jth product, ε is the elasticity of substitution between products ($\varepsilon > 1$), and γ is the marginal disutility of labor ($\gamma > 1$).

Entrepreneur i's production function is given by

$$Y_i(t) = L_i(t)e^{\theta_j(t)}, \tag{2}$$

where $Y_i(t)$ is entrepreneur i's output and $\theta_j(t)$ is a product-specific productivity shock, which has zero mean and a constant variance σ_θ^2.

The following cash-in-advance constraint defines the relationship between total spending and real money balances:

$$Y(t) = \frac{M(t)}{P(t)}, \tag{3}$$

where $Y(t)$ is the economy-wide output, $M(t)$ is nominal money supply, and $P(t)$ is the price index corresponding to the economy-wide consumption basket. That is, $(P(t) = \sum_{j=1}^{N} \omega_j P_j(t))$, where ω_j is the expenditure weight for consuming product j $(\sum_{j=1}^{N} \omega_j = 1)$ and $P_j(t)$ denotes the average price of product j.

Then, using Equations (1)–(3), the demand for the jth product can be expressed as a fraction of aggregate spending and money balances:

$$Y_j^D(t) = \left[\frac{M(t)}{P(t)}\right]\left[\frac{P_j(t)}{P(t)}\right]^{-\varepsilon}. \tag{4}$$

Next we turn to the price-setting behavior. When each entrepreneur i sets his product price in every period after observing aggregate (monetary) and productivity shocks, the entrepreneur would choose a price that maximizes utility, subject to the constraints in Equations (2)–(4). In logarithmic terms, the optimal price of entrepreneur i producing good j in the flexible price

equilibrium is given by

$$p_{ij}^{*}(t) = vm(t) + (1 - v)p(t) - w\theta_j(t), \tag{5}$$

where the lowercase letters denote logarithms (for example, $p = \ln P$), $v = \dfrac{\gamma - 1}{1 + \varepsilon\gamma - \varepsilon}$ and $w = \dfrac{\gamma}{1 + \varepsilon\gamma - \varepsilon}$ (both v and w are positive and inside the unit circle).

When an entrepreneur determines product price for several periods at the time, the goal is to choose a price that will minimize the total loss owing to deviations from the optimal price $p_j^{*}(t+k)$ for period $t+k(k \geq 0)$. The expected loss (assuming a two-period contract and no discounting) is given by a quadratic loss function (Ball and Romer, 1989):

$$Z_{ij}(t) = \frac{1}{2}[(p_{ij}(t) - p_{ij}^{*}(t))^2 + E(t)(p_{ij}(t+1) - p_{ij}^{*}(t+1))^2]. \tag{6}$$

This would result in a price-setting rule of the following form:

$$x_{ij}(t) = \frac{1}{2}[p_{ij}^{*}(t) + p_{ij}^{*}(t+1)], \tag{7}$$

where $x_{ij}(t)$ is the logarithm of the price set by entrepreneur i producing j at period t. After substituting for $p_{ij}^{*}(t+k)$ for all k, and using Equation (5), we obtain

$$x_{ij}(t) = p_{ij}^{*}(t) + \frac{1 - v}{2}[E(t)p(t+1) - p(t)]. \tag{8}$$

That is, when entrepreneur i sets the price for two periods at the time, the optimal price at t is equal to the optimal price in a flexible economy, $p_{ij}^{*}(t)$, plus expected change in the price of product j, based on information available at time t.

Different producers in the economy adopt different pricing rules. Some of them adjust their prices every period, whereas others opt for a multiperiod adjustment strategy. Different price-setting strategies among the producers of similar products could result in staggering (that is, a portion of entrepreneurs set prices each period for multiple periods) or synchronization (that is, all entrepreneurs set their prices at the same period for multiple periods). As discussed in Ball and Romer (1989), these strategic choices lead to alternative pricing dynamics (in their paper, they also analyze the stability and optimality of alternative strategies).

The average price of product j is defined as $p_j(t) = \dfrac{1}{k}\sum_{i=1}^{k} p_i(t)$. Let some firms set prices every period (the fraction of these firms is denoted by λ_j, which lies within the unit circle). The remaining firms producing the jth product, $1-\lambda_j$, adopt a two-period pricing strategy. One-half of them adjust their prices every other period (staggered), when they receive the productivity shock. Then the average price of product j is given by

$$p_j(t) = \lambda_j p_j^{*}(t) + \frac{1 - \lambda_j}{2}[x_j(t-1) + x_j(t)]. \tag{9}$$

The consumer price data for Sierra Leone is composed of only the average price for each item included in the consumer price index. Defining the average price as in Equation (9) allows us to relate the observed price to the entrepreneurs' underlying (and unobserved) pricing behavior. Of course, strategic choices are much more complex in reality, but the present model has enough structure to help illustrate some of the key features relevant for this paper. Inserting Equation (8) into (9) for periods $t-1$ and t yields

$$p_j(t) = \frac{1+\lambda_j}{2}p_j^*(t) + \frac{(1-\lambda_j)(1-v)}{4}p_j^*(t-1) + \frac{(1-\lambda_j)(1-v)}{4}[(E(t-1)p(t) - p(t-1)) + (E(t)p(t+1) - p(t))]. \tag{10}$$

That is, when staggering is introduced in the pricing behavior, price dynamics are affected by the contemporaneous and previous period optimal prices of product j in the frictionless economy and anticipated inflation based on information at the time of price setting.

Next we solve for the economy-wide price level and price expectations. For this we need to define aggregate demand and product-specific shocks. We assume that money supply is a random walk process and subject to a shock denoted by $\xi_m(t)$, with a zero mean and a constant variance, σ_m^2. It then follows that $E(t-1)m(t) = m(t-1)$. The product-specific real shocks, $\theta_j(t)$, have no economy-wide impact, that is, $\sum_{j=1}^{N}\omega_j\theta_j(t) = 0$.

Aggregating over all j products, and using Equation (5), the price level becomes

$$\left[\frac{3(1-\lambda(1+v))+v}{4}\right]p(t) = \frac{(1-\lambda)(1-v)}{4}[p(t-1) + E(t-1)p(t) + E(t)p(t+1)] + \frac{v(1+\lambda)}{4}[m(t)+m(t-1)]. \tag{11}$$

Note that λ is the economy-wide equivalent of λ_j, defined as $\sum_{j=1}^{N}\omega_j\lambda_j = \lambda$. Next, we take expectations of Equation (11) at time $t-1$:

$$E(t-1)p(t) = \frac{2v(1+\lambda)}{(1+\lambda)(1-v)-\lambda v}\left[m(t-1) + \frac{1}{2}p(t-1) + \frac{1}{2}E(t-1)p(t+1)\right]. \tag{12}$$

This is a second-order difference equation and has the following solution:

$$E(t-1)p(t) = \rho(1-\lambda)p(t-1) + ((1-\rho(1-\lambda))m(t-1)), \tag{13}$$

where $\rho = \frac{1-\sqrt{v}}{1+\sqrt{v}} \in (0,1)$ (see Ball and Romer, 1989). However, heterogeneity in the pricing strategy (Carvalho, 2006) modifies the coefficient of price inertia (λ).

The price level is given by

$$p(t) = \rho(1-\lambda)p(t-1) + \frac{1+\lambda-\rho(1-\lambda)}{2}m(t) + \frac{(1-\lambda)(1-\rho)}{2}m(t-1). \quad (14)$$

This is a generalized form, which accommodates various specific cases. When $\lambda = 1$ (that is, all entrepreneurs change their prices each period), then $p(t) = m(t)$. When $\lambda = 0$ (all entrepreneurs use a staggered pricing strategy), the price level becomes a function of lagged price level and current and lagged money, that is,

$$p(t) = \rho p(t-1) + \frac{1-\rho}{2}[m(t) + m(t-1)].$$

According to Equation (14), price or inflation inertia can arise as a result of different pricing strategies followed by the entrepreneurs. For example, if a large proportion of entrepreneurs adopt a contemporaneous pricing strategy, then inertia declines as λ becomes large. This may be, for example, because economic uncertainties have increased. A higher λ will reduce the lagged monetary effects on the price level.

Inserting Equation (14) into Equation (8), and using Equation (5), yields

$$x_{ij}(t) = A_1 p(t-1) + A_2 m(t-1) + A_3 \xi_m(t) - w\theta_j(t), \quad (15)$$

where

$$A_1 = \frac{1-v}{2}[1 + (\rho(1-\lambda))^2] > 0,$$

$$A_2 = v + (1-v)(1-\rho(1-\lambda)) > 0,$$

and

$$A_3 = v + \frac{1-v}{2}[1+\lambda-\rho(1-\lambda)] > 0.$$

That is, the optimal price of product j depends on the lagged price level and money supply as well as the contemporaneous money and real shocks. All coefficients become smaller as the value of λ becomes larger. That is, as the economy-wide share of entrepreneurs using current period pricing strategy increases, past information becomes less relevant for a pricing decision.

Inserting Equations (14) and (15) into Equation (9) yields

$$p_j(t) = B_1 p(t-1) + B_2 p(t-2) + B_3 m(t-1) + B_4 m(t-2) + B_5 \xi_m(t) - B_6 \theta_j(t) - B_7 \theta_j(t-1), \quad (16)$$

where

$$B_1 = \lambda_j \rho(1-\lambda) + \frac{1-\lambda_j}{2} A_1 > 0,$$

$$B_2 = \frac{1-\lambda_j}{2} A_1 > 0,$$

$$B_3 = \lambda_j \left(v + \frac{1-v}{2} A_2 \right) + \frac{1-\lambda_j}{2} (A_2 + A_3) > 0,$$

$$B_4 = \frac{1-\lambda_j}{2} (A_2 - A_3) > 0,$$

$$B_5 = \frac{1+\lambda_j}{2} A_3 > 0,$$

$$B_6 = \frac{1+\lambda_j}{2} w > 0, \text{ and}$$

$$B_7 = \frac{1-\lambda_j}{2} w > 0.$$

According to Equation (16), the average price of product j is influenced by the economy-wide inertia, $\rho(1-\lambda)$, as well as the sector-specific inertia $(1-\lambda_j)$. That is, there is a spillover from the economy-wide inertia to the product-specific price. The lagged price level and money supply and the contemporaneous monetary and sector-specific real shocks positively affect the average product price. The changes in the product j price become more synchronized with the price level when λ_j increases, but less so with an increase in λ.

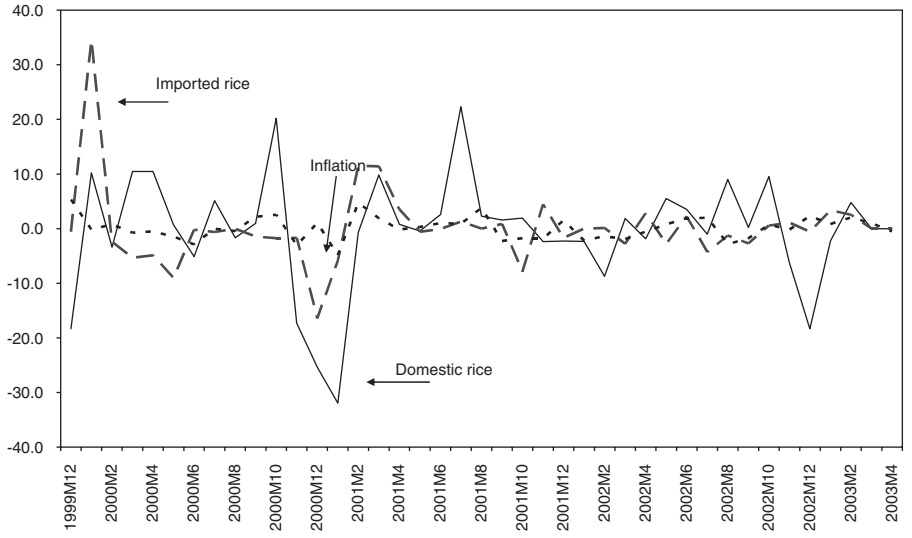
VI. Time-Series Analysis of Price Dynamics in Sierra Leone

Below we will analyze the causes of price volatility in Sierra Leone. The theoretical model in Section V explains how price dynamics is influenced by entrepreneurs' pricing behavior and also provides a rationale for price inertia when agents adopt heterogeneous pricing strategies (for comparison, see Ball and Romer, 1989).

The Price of Rice

Empirically, the estimated parameters of contemporaneous and lagged explanatory variables will shed light at the product level on the

Figure 4. Inflation and Change in the Price of Rice, 1999M12–2003M4
(Percent of monthly change)



Sources: Sierra Leonean authorities and IMF staff estimates.

entrepreneurs' pricing behavior (as illustrated in Equation 16). Rice is a key staple in Sierra Leone and its large weight in the consumer price index suggests that changes in the price of rice have a significant impact on the overall price level, as well as on the welfare of the public. Sierra Leone produces local rice, but it also imports rice to supplement the domestic supply. Imported rice is about twice as expensive as domestic rice, but better in quality. Furthermore, the prices of domestic and imported rice have been much more volatile than the aggregate price level (Figure 4).

We estimated Equation (16) in difference form that illustrates the dynamics of price changes for local and imported rice prices. Because of the substitutability between local and imported rice, we also inserted current period and two lagged values of the change in price of imported (local) rice into the price equation for local (imported) rice. As indicated in Table 4, changes in the price of local rice are largely determined by changes in the price of imported rice. An increase in the price of imported rice will increase the price of local rice by about 67 percent in the same period. This implies that the producers of local rice use the price of imported rice to mark up their prices. Other variables were not statistically significant, which points to a large λ_j. However, high price volatility has also reduced the overall fit of the equation. On the other hand, changes in the price of imported rice offer a different picture. The lagged values of economy-wide inflation and money growth obtained statistically significant estimates, but the cross-price effect from changes in the price of local rice is insignificant in the estimation. For imported rice, the results are consistent with the presence of large λ and λ_j.

Table 4. Substitution Effect Between Local and Imported Rice, 1999M12–2003M4

	Estimate	Standard Error
(Dependent variable is the price of local rice)		
Change in the price of imported rice (t)	0.67	0.33*
Sigma		0.10
R^2		0.10
Log-likelihood function		91.38
Normality test (probability)		0.05
AR 1–4 test (probability)		0.41
ARCH 1–4 test (probability)		0.56
Heterogeneity test (probability)		0.26
(Dependent variable is the price of imported rice)		
Constant	−0.02	0.01**
$\Delta m(t-1)$	0.50	0.21*
$\Delta m(t-2)$	0.41	0.22*
$\pi(t-1)$	0.16	0.06**
$\pi(t-2)$	−0.17	0.06**
Sigma		0.04
R^2		0.51
Log-likelihood function		132.78
Normality test (probability)		0.81
AR 1–4 test (probability)		0.25
ARCH 1–4 test (probability)		0.11
Heterogeneity test (probability)		0.34

Sources: Sierra Leonean authorities and IMF staff estimates.

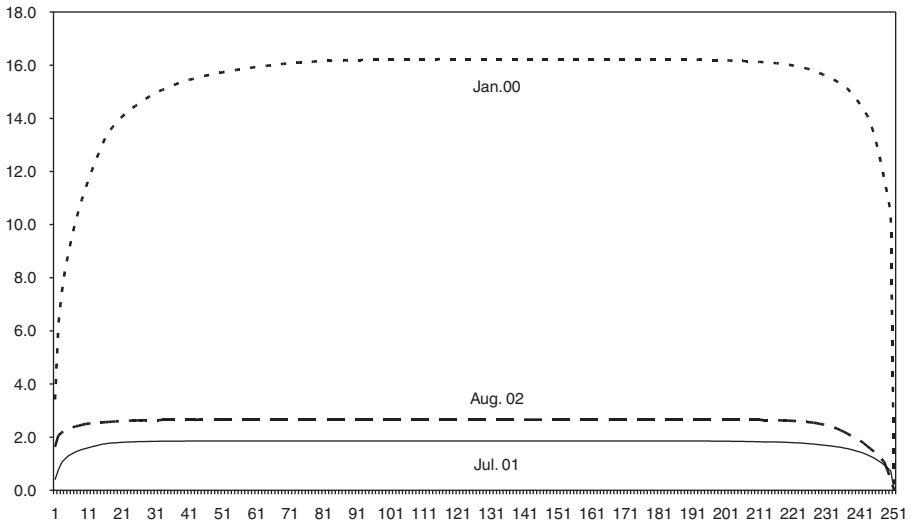
Notes: * indicates statistical significance at 5 percent level; ** indicates statistical significance at 1 percent level.

Relative Price Variability

The results for cross-sectional analysis indicate that the interval of successive price changes may have become shorter, reflecting economic uncertainty. Entrepreneurs adjust their prices more frequently in an uncertain environment in order to minimize losses to their businesses. When prices are adjusted flexibly, aggregate demand shocks do not influence relative prices because all prices move in tandem. Only sector-specific shocks affect the relative prices. In an economy where some entrepreneurs set their product prices for several periods each time, aggregate shocks would also influence relative prices (see Equation (16)).

In order to analyze relative price movements in Sierra Leone, we construct a simple measure to calculate the cumulative impact of relative price changes in a period (the methodology is from Suvanto and Hukkinen, 2004).

Figure 5. Distribution of Relative Price Changes
(Relative price variability)



Sources: Sierra Leonean authorities and IMF staff estimates.

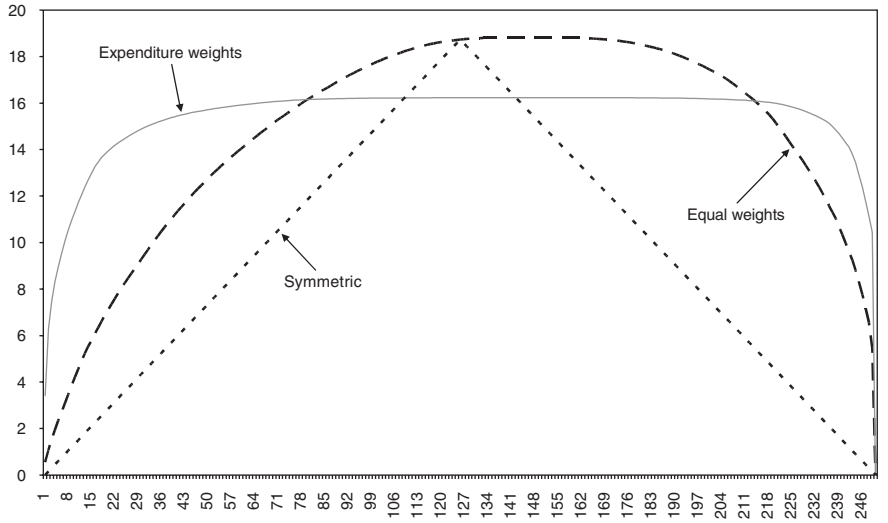
The cumulative sum for the first κ items is defined as

$$CRP(t, \kappa) = \sum_{j=1}^{\kappa} \omega_j(\pi_j(t) - \pi(t)), \tag{17}$$

which is weighted by the expenditure share of product j (where $\kappa = 1, \ldots, N$). The index ranks relative price changes by size (the largest monthly price change comes first, the second-largest next, and so on). Note that $CRP(t, \kappa) = 0$ for $\kappa = N$ (that is, when all items have been included). Figure 5 shows the cumulative distributions of relative price changes for selected months. The relative price distributions for all other months were broadly similar to the ones shown here. January 2000 is an exception, because the relative price changes were unusually large. The large relative price variability in January 2000 was also combined with negative monthly inflation (−0.25 percent), which shows that rising relative price variability might not always be associated with high or rising inflation (see, for instance, Fischer (1982) in the context of the U.S. and German hyperinflations).

An important feature of the distribution is that it has a large flat area and very steep edges. It reflects the fact that in Sierra Leone relative price movements were typically associated with a few products having a large weight in the consumer price index. Figure 6 illustrates this. The solid line is the actual cumulative distribution of the relative prices in January 2000, as in Figure 5. The dashed line is the cumulative distribution of the relative prices assuming that the expenditure weights are identical for all products ($\omega_j = 1/251$ for all j). The difference between solid and dashed lines reflects the largest

Figure 6. Cumulative Relative Price Distribution with Different Weights, January 2000
(Relative price variability)



Sources: Sierra Leonean authorities and IMF staff estimates.

and most heavily weighted relative price changes in Sierra Leone's consumer price index. The dotted line (labeled as "symmetric") assumes that one-half of all prices rise and one-half fall each by an equal amount. Because this curve is below the dotted line, the prices of some items changed much more than others in reality.

The steepness of the distribution at both ends reflects the presence of fat tails (high kurtosis). The long flat area on the top of the distribution is a reflection of the fact that a large portion of relative price changes are concentrated around the peak of the distribution. The cumulative distribution is skewed to the left (right) when large positive (negative) deviations dominate.

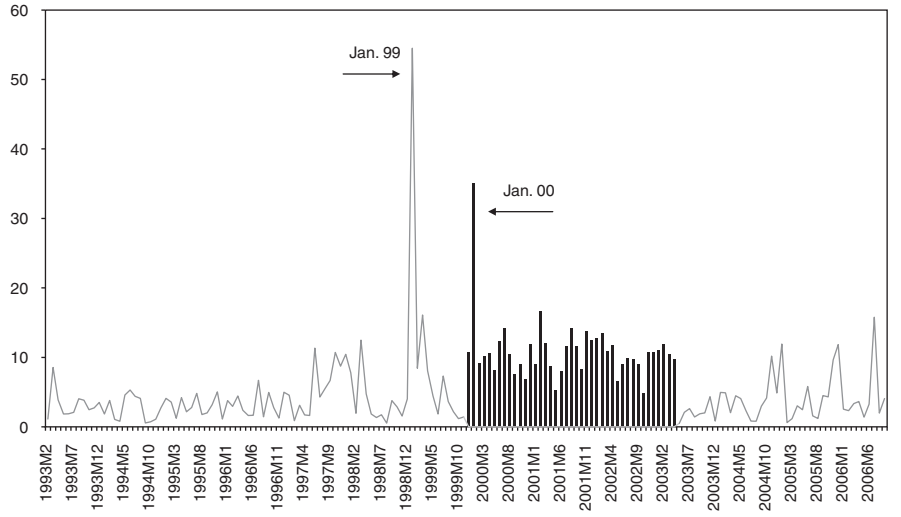
Relative price variability for product j is given as $RPV_j(t) = \omega_j(\pi_j(t) - \pi(t))^2$. Summing over all products yields

$$RPV(t) = \sum_{j=1}^{N} \omega_j(\pi_j(t) - \pi(t))^2. \tag{18}$$

Figure 7 displays the estimated relative price variability (its standard deviation) in Sierra Leone during 1993–2006.[6] The data suggest that inflation

[6]The estimates for December 1999 to April 2003 were from the detailed consumer price data. For the longer periods, the estimated variances were based on less disaggregated data containing 13 broad categories of products; hence, the levels of relative price variability may not be fully comparable between the two series. See Parsley (1996).

Figure 7. Monthly Relative Price Variability, February 1993–September 2006
(Standard deviation)



Sources: Sierra Leonean authorities and IMF staff estimates.

and relative price movements are not always positively correlated. This reflects the specific causes underlying price changes in each case. An increase in the relative price variability was combined with a rising price level in January 1999, but with a falling price level in 2000. On the other hand, the variability of relative prices did not change substantially in February 1998 when the price level increased sharply.[7]

Table 5 reveals additional information about the variability of relative prices. Relative price variability has a low and negative correlation with inflation in Sierra Leone (opposite to the literature), suggesting the dominance of real shocks (here we do not distinguish between anticipated and unanticipated inflation). The correlation between inflation and skewness of relative price changes is positive (see Figure 8), which would be suggestive of menu-cost pricing (Ball and Mankiw, 1995). Inflation is also moderately correlated with kurtosis of the relative price variability.

Have deviations in relative prices persisted? Persistent deviations in relative price changes suggest that productivity or sector-specific supply

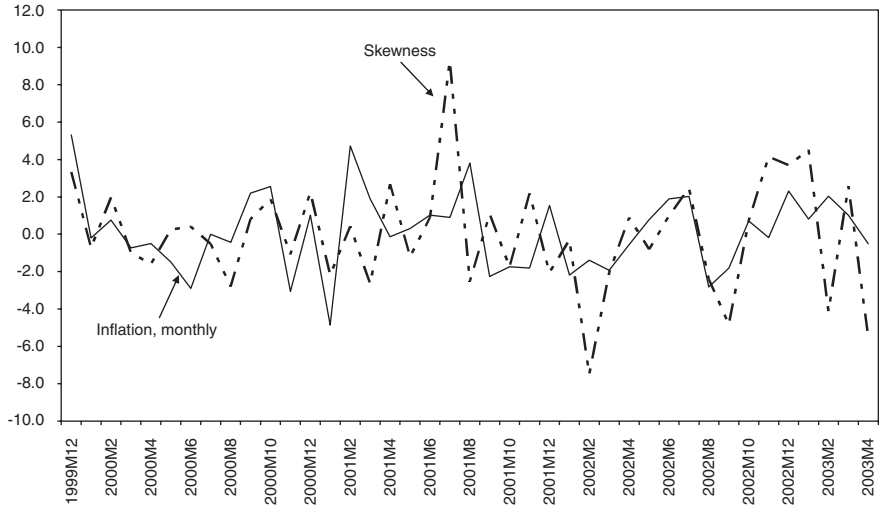
[7]Political events were important for price developments. President Kabbab was overthrown in a military coup in May 1997, which was followed by the most violent period of the civil war. Military interventions by the Economic Community of West African States Ceasefire Monitoring Group (ECOMOG) liberated Freetown in February 1998, removed the rebels, and reinstated President Kabbab to power. In January 1999, the rebels attacked Freetown and looted a large part of the capital. A United Nations peacekeeping force (UNAMSIL) arrived in November 1999 and reinforced the ECOMOG troops, which eventually led to a permanent peace.

Table 5. Selected Correlations, 1999M12–2003M4

	Inflation	RPV	Skewness of RPV	Kurtosis of RPV
Inflation	1.00			
RPV	−0.03	1.00		
Skewness of RPV	0.38	−0.05	1.00	
Kurtosis of RPV	0.15	−0.07	0.00	1.00

Sources: Sierra Leonean authorities and IMF staff estimates.
Note: RPV = relative price variability.

Figure 8. Skewness of Relative Prices and Inflation, December 1999–April 2003
(Percent)



Sources: Sierra Leonean authorities and IMF staff estimates.

shocks may dominate the price dynamics. When relative price variability is regressed against a constant and its one-period lag, we obtain a significant and positive serial autocorrelation for the period January 1994–March 2004, but not for December 1999–April 2003 (Table 6). As discussed in Parsley (1996), aggregation could lead to spurious correlation and hence explain the divergence in these two results.

Price Volatility and Monetary Policy

During the period under this study, inflation was muted and the price level stayed virtually unchanged. However, inflation was volatile. The volatility can be explained by the large weights of a small number of items included in the consumer price index. A small number of products represent about two-

Table 6. Persistency of Relative Prices

	Estimate	Standard error[1]
(1994M1–2004M3)		
Constant	82.80	24.09**
Lagged dependent variable[2]	0.59	0.11**
Sigma		185.89
R^2		0.35
F-test (significance)		0.00**
Durbin-Watson		1.81
(1999M12–2003M4)		
Constant	145.37	48.25**
Lagged dependent variable[2]	−0.02	0.32
Sigma		185.88
R^2		0.00
F-test (significance)		0.88
Durbin-Watson		1.07

Sources: Sierra Leonean authorities and IMF staff estimates.
Notes: ** indicates statistical significance at 1 percent level.
[1]Standard errors are heteroscedastic consistent.
[2]Relative price variability.

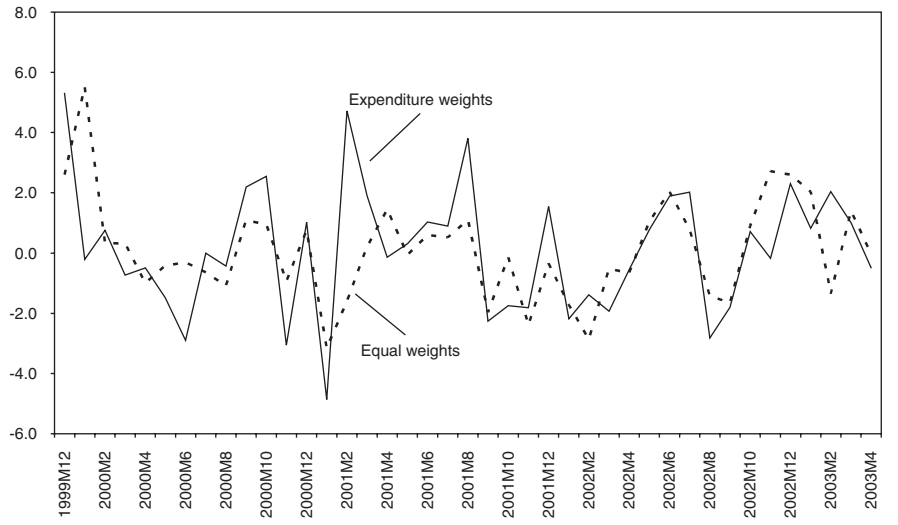
thirds of the total expenditure, which indicates a high level of concentration. This has important policy implications. In this group, there are several staple food items, such as domestic and imported rice and palm oil, as well as a number of nonfood items (such as firewood, soap, rental rates, and charges for various utilities). The prices of these products changed frequently, while other prices stayed unchanged for a longer period of time (for example, city transportation).

The relative weight of few items in the consumer price index has a large impact on inflation and its volatility. To illustrate this, we compare monthly inflations using actual expenditure weights and equal weighting (Figure 9). Although trend inflation is the same in both, the volatility is much reduced with even weighting.

If we exclude five items with the largest price increases and decreases from the consumer price index, it will lower inflation variability by about 75 percent (Figure 10). When we exclude 20 items with the highest price increases and decreases from the same index, inflation variability drops close to zero and is only weakly correlated with movements in actual inflation.

The volatility of prices, even when the price level is stable, as was the case during the sample period, represents an important challenge for the policymaker. Particularly, the concentration of price volatility on only a few heavily weighted items in the consumer price index compounds these effects.

Figure 9. The Importance of Weights for Measuring Inflation 1999M12–2003M4
(Percent per month)



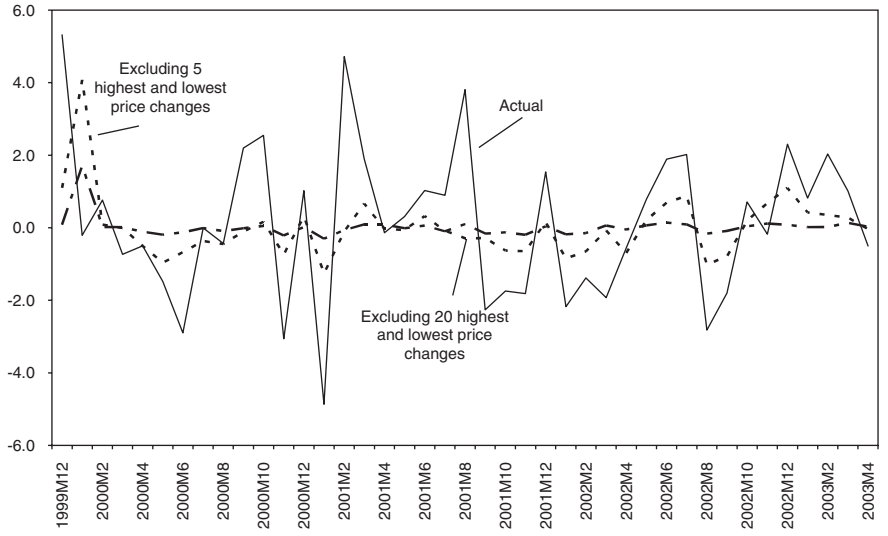
Sources: Sierra Leonean authorities and IMF staff estimates.

These results suggest that the monetary authorities need to pay attention to the underlying causes of inflation and develop a "core" inflation measure that would be suitable for policy implementation in Sierra Leone. The core inflation measure needs to be tailored to reflect appropriately the large weights in the index associated with food items. The rationale for targeting a less volatile inflation measure is that changes in volatile prices, such as food items, are usually caused by product-specific (temporary) shocks beyond the control of the monetary authorities. In Sierra Leone, weather is also an important factor in determining food prices because heavy rains combined with inadequate roads have affected the availability of agricultural products in the local markets. This in part explains the volatility of commodity prices in the country. Exclusion of all food and energy prices from the core measure, as is often done in advanced countries, however, may not be appropriate for Sierra Leone.

VII. Conclusions

A key theme employed throughout this paper has been price volatility, which we have studied using micro-level price data for Sierra Leone that cover a three-and-a-half-year period. This period was unique because the price level was broadly unchanged during the period while relative prices displayed considerable volatility. The study benefited from a longer, historical perspective of the price developments in the country, which enhanced our understanding of the more recent price developments in Sierra Leone. Nevertheless, the lack of producer-specific product price data (data were

Figure 10. Alternative Inflation Measures, 1999M12–2003M4
(Percent per month)



Sources: Sierra Leonean authorities and IMF staff estimates.

obtained from monthly averages of these prices) limited the scope of the research and prevented a direct analysis of price-setting behavior at the enterprise level.

The results for Sierra Leone are broadly supportive of the previous research, but we have also brought to the surface some features that are specific to this country. Because of the virtual nonexistence of research involving developing countries, it is impossible to assess the broad implications of our results. Therefore, further research on price dynamics in developing countries using micro-level data would be well justified to establish whether similar conclusions could be obtained for other developing countries.

We model price dynamics at the product and economy-wide levels based on entrepreneurs' price-setting behavior. We also assume heterogeneity among the producers regarding their price-setting strategies, which is shown to give rise to spillover effects from the aggregate economy to the product level. Empirical results for Sierra Leone support the implications of the model and show that inflation inertia has not been a significant factor in the recent past. This suggests the dominance of event-based price-setting behavior.

An important outcome of this study is that price variability is largely driven by changes in a few product prices that are heavily weighted in the consumer price index. It has led to high relative price variability in Sierra Leone even during a period of relatively stable price levels. Rice is an important staple food in Sierra Leone, and it has a large weight in the consumer price index. Volatility in the price of rice therefore has important welfare implications, particularly for the poor.

Furthermore, we have also stressed that inflation volatility has complicated monetary policy implementation in Sierra Leone and has weakened the monetary transmission. As a remedy for this problem we suggested that the monetary authorities introduce ''core inflation'' as the key policy objective, which would exclude the volatile prices from the price index. Although the use of a narrow inflation measure is common among the central banks around the world, it should take into account the specific circumstances in Sierra Leone (such as the high share of food prices in the overall consumer price index).

Regarding pricing behavior, the evidence suggests that entrepreneurs are likely to respond to events when adjusting their product prices, given the lack of statistically significant inertia in these prices, whereas time-dependent pricing is probably less common. We argued that this has been a response to inflation variability, which has led to shorter pricing intervals, as shown in the cross-sectional data. Inflation inertia was statistically significant during the earlier period, which highlights the importance of maintaining price stability and low price volatility over a longer period of time for entrepreneurs' price-setting behavior.

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