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Inflation, Interest, and Relative Prices

In setting interest rates on treasury bills, the market appears to respond only to the common part of the expected inflation rates of different goods. However, there are seasonals in expected inflation rates which are different for different goods. We suggest that these differential seasonals reflect real costs of providing different goods to the market at different times of the year and hence are properly ignored by the market in setting interest rates. Finally, there is increasing similarity in the movement of the unexpected inflation rates of different goods for longer measurement intervals. In part, we interpret this as the result of a gradual reallocation of resources in response to surprise shifts in supply or demand conditions. The tests use data for the U.S. Consumer Price Index and its major subcomponents from 1953 to 1977.

Irving Fisher ([1930] 1965) first elaborated the hypothesis that interest rates contain market forecasts of future inflation rates. If the market is efficient or rational, it makes the best possible forecasts of future inflation rates, given the information available when interest rates are set. However, the hypothesis that interest rates contain the best possible assessments of expected future inflation rates is only clear-cut in a world where the inflation rate is unambiguous, as is true, for example, when relative prices are constant so that all goods experience the same inflation rate. If relative prices change, an overall inflation rate may be difficult to define even for an individual consumer. In fact, relative prices vary substantially during the 1953–77 period that we study.

We propose a model to explain the observed behavior of interest rates and money prices of consumption goods which allows for relative price changes but is nevertheless in the spirit of Fisher. The model attributes the "Fisher effect" relationships between interest rates and inflation rates observed in the data to a component of expected inflation rates which is common to all

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goods. The data also indicate that the expected inflation rates of different goods contain noncommon components which are not incorporated in interest rates. The model attributes this result to seasonals in production and storage costs which give rise to seasonals in expected inflation rates that differ in timing and magnitude across goods and are properly ignored by the market in setting interest rates.

Finally, the data indicate that the unexpected components of the inflation rates of different goods show more similarity of behavior over longer intervals than over shorter intervals. The model explains the short-term behavior of unexpected inflation rates in terms of surprises which are to some extent common to all goods but which also differ across goods as a consequence of unexpected shifts in demand and supply conditions. However, the model hypothesizes that the market eventually induces reallocations of resources in response to differential surprises so that there is more similarity in the longer-term inflation rates of different goods than in shorter-term inflation rates.

I. The Model

The inflation rate for any commodity i in period t, $\tilde{\Delta}_{it}$, can be expressed as

$$\tilde{\Delta}_{it} = K_t + E(\tilde{\eta}_{it} | \phi_{t-1}) + \tilde{\epsilon}_{it}, \quad (1)$$

where tildes denote random variables, ϕ_{t-1} is the set of information available at time $t-1$, K_t is the part of the expected inflation rate for good i which is common to all goods, $E(\tilde{\eta}_{it} | \phi_{t-1})$ is the part of the expected inflation rate for good i which is not common to all goods, and $\tilde{\epsilon}_{it}$ is a random disturbance, the unexpected inflation rate for good i. From (1), the expected inflation rate for good i has two components,

$$E(\tilde{\Delta}_{it} | \phi_{t-1}) = K_t + E(\tilde{\eta}_{it} | \phi_{t-1}). \quad (2)$$

We emphasize that K_t is not to be confused with $E(\tilde{\Delta}_t | \phi_{t-1})$, the expected value of the overall inflation rate. If we multiply through (1) by the appropriate weight for component i and then sum across components, we can express the overall inflation rate $\tilde{\Delta}_t$ as

$$\tilde{\Delta}_t = K_t + \sum_i w_i E(\tilde{\eta}_{it} | \phi_{t-1}) + \tilde{\epsilon}_t, \quad (3)$$

with

$$E(\tilde{\Delta}_t | \phi_{t-1}) = K_t + \sum_i w_i E(\tilde{\eta}_{it} | \phi_{t-1}). \quad (4)$$

Thus, the expected value of the overall inflation rate contains both K_t, the common part of expected inflation rates, and a weighted average of the differential parts of the expected inflation rates of individual goods, with no presumption that this weighted average is equal to zero.

The common term in the expected inflation rates of different goods, K_t, has a standard interpretation. In order to obtain equilibria in the markets for different goods, firms in different industries adjust their outputs now, vis-à-vis planned future outputs, so that expected returns, net of appropriate risk adjustments, are equated across industries. Generally this implies a tendency to adjust outputs so that the expected inflation rates of different goods are equalized.

However, equalization of expected returns across industries may also require "seasonals" in the inflation rates of some goods. For some goods—for example, fruits and vegetables—production may be seasonal while demand occurs more smoothly throughout the year. To induce storage, that is, to offset the real costs of storing the seasonal output, it may be necessary that the expected inflation rates of some goods have seasonals. Likewise, demand for some goods, for example, Christmas and Easter items, new automobiles, and apparel, may be seasonal whereas efficiency implies that such items are produced throughout the year. Again, we can expect to observe seasonals in the prices of such items, where the role of the seasonals is to offset the costs of storage.

Suppose equalizing expected returns from the production of different goods requires a differential term $E(\tilde{\eta}_{it} | \phi_{t-1})$ in the expected inflation rate for good i which simply offsets a seasonal cost in providing good i to the market. Then, netting out any risk premium, the expected nominal return at $t-1$ to the activity of supplying good i to the market at t is

$$E(\tilde{r}) + K_t, \tag{5}$$

where $E(\tilde{r})$ is the expected real return, assumed to be constant, and where the absence of i subscripts indicates that risk-adjusted expected nominal returns are the same for all goods. Note that since the differential term $E(\tilde{\eta}_{it} | \phi_{t-1})$ in the expected inflation rate for good i in equation (2) just offsets a seasonal in the cost of supplying good i to the market, it does not show up in the expected return for period t to the suppliers of the good.

On the other hand, suppose for the moment that the one-period interest rate is set to reflect both the common and the noncommon parts of the overall expected inflation rate; that is,

$$\begin{aligned} R_t &= E(\tilde{r}) + E(\tilde{\Delta}_t | \phi_{t-1}) \\ &= E(\tilde{r}) + K_t + \sum_i w_i E(\tilde{\eta}_{it} | \phi_{t-1}), \end{aligned} \tag{6}$$

where R_t is the nominal interest rate set at $t-1$ for the period from $t-1$ to t. When the weighted average of the $E(\tilde{\eta}_{it} | \phi_{t-1})$ in (6) is positive, investment in a one-period bond dominates the activity of providing any good i to the market. On the other hand, if we allow negative values of $E(\tilde{\eta}_{it} | \phi_{t-1})$ as a consequence of abnormally low costs of supplying good i to the market for period t, the last term in (6) could be negative, in which case bonds are dominated by the activity of providing goods to the market.

Since dominance is inconsistent with equilibrium across markets, attaining equilibrium in the bond market as well as in the markets for goods implies that the interest rate does not respond to that part of the overall expected inflation rate which reflects differing costs of providing goods to the market at different points in production-storage cycles. The market must set the nominal interest rate

$$R_t = E(\tilde{r}) + K_t, \tag{7}$$

so that suppliers of goods and holders of bonds face the same risk-adjusted expected nominal return.

Finally, we have discussed differential expected inflation rates in terms of differential "seasonals." However, these differential seasonals might be any sort of pattern in the expected inflation rate of a good which is not common to all goods. Moreover, we can conceive of common seasonals in the inflation rates of all goods whose role is to offset seasonals in the production costs of all goods. In all such cases, the reasoning of this section would imply that the market should ignore these seasonals in setting the nominal interest rate R_t.

II. Tests of the Model

Results for the CPI Components

Using (7) to substitute for K_t in (1), the proposition that the interest rate only responds to the common part of expected inflation rates implies that the inflation rate for good i can be expressed as

$$\tilde{\Delta}_{it} = -E(\tilde{r}) + R_t + E(\tilde{\eta}_{it} | \phi_{t-1}) + \tilde{\epsilon}_{it}. \tag{8}$$

Since the hypothesis is that the market ignores $E(\tilde{\eta}_{it} | \phi_{t-1})$ in setting the interest rate, $E(\tilde{\eta}_{it} | \phi_{t-1})$ and R_t should be independent. An estimated regression of $\tilde{\Delta}_{it}$ on R_t should produce a coefficient for the interest rate equal to 1.0, and the residuals should reflect the time series behavior of $E(\tilde{\eta}_{it} | \phi_{t-1})$.

Table 1 summarizes estimated regressions of the 1-month inflation rates of the U.S. Consumer Price Index (CPI) and nine of its major components on 1-month treasury bill rates for the period 1953–77. An inflation rate for any month t is the natural log of the ratio of the values of the relevant price index for months t and $t-1$. Like the inflation rates, the interest rates are continuously compounded; that is, R_t is the

TABLE 1 **Regressions of Monthly Inflation Rates on One-Month Treasury Bill Rates, 1/53–7/71 and 1/75–12/77, $N = 259$ ($\Delta_{it} = \alpha_i + \beta_i R_t + \epsilon_{it}$)**

Index	α_i	β_i	$\bar{R}^2$	$S(\epsilon_i)$	ρ_1	ρ_2	ρ_3	ρ_{12}
CPI	−.0009	1.12	.35	.0020	.20	.16	.04	.18
	(.0003)	(.09)						
Food	−.0010	1.04	.05	.0061	.28	.03	−.16	.18
	(.0009)	(.28)						
Apparel	−.0008	.90	.05	.0050	.16	−.21	−.25	.82
	(.0007)	(.23)						
Transportation	−.0007	1.09	.05	.0061	.04	.03	.05	.31
	(.0009)	(.28)						
Household furnishings	−.0017	1.19	.25	.0027	.01	.00	.08	.45
	(.0004)	(.13)						
Health and recreation	.0001	.96	.36	.0017	.17	.25	.14	.20
	(.0002)	(.08)						
Home purchase price	−.0019	1.46	.24	.0034	.35	.17	−.02	.11
	(.0005)	(.16)						
Home ownership	−.0016	1.64	.35	.0030	.37	.09	−.03	.06
	(.0004)	(.14)						
Rent	.0006	.55	.17	.0016	.49	.55	.45	.29
	(.0002)	(.08)						
Fuel and utilities	.0003	.92	.08	.0042	.30	.23	.15	.35
	(.0006)	(.19)						

NOTE.—The coefficient of determination, $\bar{R}^2$, is adjusted for degrees of freedom; $S(\epsilon_i)$ is the standard error of the regression residuals; and ρ_τ is the estimated residual autocorrelation at lag τ. Standard errors of the estimated regression coefficients are shown in parentheses.

natural log of one plus the simple interest rate observed at the end of month $t-1$ on a bill that matures at the end of month t.[1]

The nine components of the CPI for which results are shown in table 1 represent a mutually exclusive and exhaustive decomposition of the index, except that the home purchase price index is a subcomponent of the home ownership index. The breakdown of the CPI into these nine components is arbitrary, and it probably would be desirable to show more detailed results. However, if one wants continuous monthly data back to 1953, the additional feasible breakdowns are quite limited. More important, the anomalous results that will confront us have little to do with excessive aggregation.

The starting date, January 1953, for the tests in table 1 corresponds to a major upgrading of the CPI in which the coverage of the index (number of goods and services whose prices are sampled) is expanded and monthly sampling of prices becomes a more general rule. The tests

1. Keep in mind that the interest rate R_t is known at $t-1$. Its subscript t reflects the fact that R_t is also the 1-month return on the bill realized at t. In contrast, inflation rates observed at t are random variables at $t-1$. The interest rates are derived from the quote sheets of Salomon Brothers; see Fama (1976), chap. 6.

stop in July 1971, the month before the Nixon administration instituted price controls. Since the controls did lead to shortages, reported inflation rates during the period of price controls probably understate true changes in purchasing costs to consumers, while measured inflation rates overstate true inflation rates during the periods, primarily 1973–74, when the controls were lifted. The tests pick up again in January 1975 and continue through 1977.[2]

There is another important change in the way the CPI is constructed at the beginning of 1964. The coverage of the index is again extended, and the weights assigned to different items are updated in line with the 1960–61 Consumer Expenditure Survey. Perhaps more important, the method of imputing prices for goods and locations not actually sampled in a given month changes substantially. The food and fuel components, about 28% of the CPI, are priced monthly in all locations. Almost all components are also priced monthly in the five major cities, and these cities account for about 30% of the CPI. Making a rough correction for overlap, we can infer that about 50% of the items and locations used to construct the CPI are sampled every month. Most other prices are collected quarterly, but on a rotating basis across locations so that there is some revision of prices each month. Prior to 1964, prices for nonsampled items were imputed from sampled prices in the five largest cities. Since the 1964 revision of the index, prices for nonsampled items and locations are held constant at their most recently sampled values.

Roughly speaking, then, since 1964 in any given month about 35% of the prices in the CPI are incorrectly reported as unchanged. About 15% of the prices reported as changed, those for locations sampled during the month that are on a quarterly sampling interval, reflect changes for the preceding 2 months as well. Since we find that the prices of goods tend to move together, these lags in the collection process introduce spurious autocorrelation in measured monthly inflation rates, which probably also explains to some extent the consistently positive lower-order (lags 1 and 2) residual autocorrelations in table 1.

As predicted by the model of equation (8), the estimated regression coefficients for the interest rate are generally close to 1.0 in table 1. Only the rent component, the home ownership component, and its subcomponent, home purchase price, have estimated coefficients for the interest rate which are more than 2 SE from unity, and coefficients within 1 SE of unity are more general. Thus, the data are broadly consistent with a one-to-one correspondence between movements in the 1-month treasury bill rate and common movements in the expected inflation rates of the CPI and its components.

2. For a more extensive discussion of the effects of the controls on interest rate–inflation relationships, see Fama (1976), chap. 6. A detailed description of the CPI and its components is in bulletin no. 1517 of the U.S. Department of Labor, Bureau of Labor Statistics (BLS), "The Consumer Price Index: History and Techniques" (1966).

The residual autocorrelations in table 1 provide evidence of non-common variation in the expected inflation rates for different goods. In the regressions of the component inflation rates on the interest rate, the residual autocorrelations at the seasonal lag 12 are large for most series, and, as noted earlier, some series show lower-order residual autocorrelations that are also large. Thus, the past inflation rates of the components, which, of course, are part of the information set ϕ_{t-1}, contain information about expected component inflation rates from $t-1$ to t which is not included in the interest rate R_t set at $t-1$.

The nature of the information in past inflation rates is easily determined. Part B of table 2 shows the first 12 autocorrelations of the monthly relative price changes of the CPI components.[3] A relative price is defined as the price level of a component, p_{it}, relative to the price level for the CPI, p_t. The rate of change in the relative price of component i from $t-1$ to t is defined as

$$\ln\left(\frac{p_{it}}{p_t}\bigg/\frac{p_{i,t-1}}{p_{t-1}}\right) = \ln\left(\frac{p_{it}}{p_{i,t-1}}\right) - \ln\left(\frac{p_t}{p_{t-1}}\right) \tag{9}$$

or

$$\rho_{it} = \Delta_{it} - \Delta_t. \tag{10}$$

In words, the relative price change for component i, ρ_{it}, is its money inflation rate, Δ_{it}, less Δ_t, the inflation rate for the CPI.

For each of the CPI components, the autocorrelations of the relative price changes for the component in part B of table 2 are much the same as the residual autocorrelations in the inflation-interest rate regressions for the component in table 1. For example, the residual autocorrelations for lags 1, 2, 3, and 12 for the regression of the monthly food inflation rate on the treasury bill rate in table 1 are 0.28, 0.03, −0.16, and 0.18, whereas the corresponding autocorrelations of the monthly relative price changes for food in table 2 are 0.30, −0.01, −0.20, and 0.25. Thus, there are relative price changes that are to some extent predictable on the basis of past relative price changes; and, for reasons to be explained now, these expected relative price changes show up intact in the residuals from the regression of the component inflation rates on the interest rate.

From equation (10), the expected relative price change for component i is its expected inflation rate less the expected overall inflation rate,

$$E(\tilde{\rho}_{it}\,|\,\phi_{t-1}) = E(\tilde{\Delta}_{it}\,|\,\phi_{t-1}) - E(\tilde{\Delta}_t\,|\,\phi_{t-1}). \tag{11}$$

3. For the statistically curious, part A of table 2 shows the autocorrelations of the 1-month treasury bill rate and of the inflation rates of the CPI and its components. The average inflation rates, also shown in the table, will occupy us later.

TABLE 2 Autocorrelations of Monthly Inflation Rates and Relative Price Changes: January 1953–July 1971 and January 1975–December 1977

Index	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	ρ_8	ρ_9	ρ_{10}	ρ_{11}	ρ_{12}	$\bar{X}$	$s(X)$
						A. Inflation Rates								
Food	.31	.07	−.10	−.16	−.06	.05	.02	−.05	.05	.07	.09	.22	.0019	.0062
Apparel	.20	−.14	−.16	−.29	.20	.49	.18	−.27	−.19	−.17	.21	.90	.0017	.0052
Transportation	.09	.08	.11	.07	.02	.05	.05	.13	.09	.06	.13	.33	.0024	.0062
Household furnishings	.27	.24	.30	.31	.30	.28	.33	.29	.27	.22	.24	.60	.0017	.0032
Health and recreation	.45	.49	.42	.44	.40	.46	.42	.37	.36	.44	.38	.43	.0028	.0021
Home purchase price	.50	.35	.18	.19	.17	.23	.25	.23	.22	.26	.27	.24	.0023	.0040
Home ownership	.60	.40	.28	.28	.32	.37	.37	.41	.38	.35	.26	.23	.0030	.0037
Rent	.58	.62	.54	.59	.47	.55	.47	.45	.42	.46	.47	.46	.0021	.0018
Fuel and utilities	.35	.29	.21	.18	.23	.26	.26	.11	.20	.24	.31	.40	.0024	.0044
CPI	.48	.45	.37	.39	.37	.35	.32	.40	.43	.41	.35	.42	.0023	.0025
1-month treasury bill rate	.96	.95	.93	.91	.89	.86	.84	.82	.80	.77	.76	.75	.0029	.0013
						B. Relative Price Changes								
Food	.30	−.01	−.20	−.27	−.11	.06	.02	−.13	−.09	−.02	.10	.25	−.0004	.0048
Apparel	.15	−.20	−.21	−.34	.12	.47	.10	−.32	−.23	−.23	.15	.78	−.0006	.0051
Transportation	.00	.02	.06	−.10	−.07	−.01	−.03	−.01	.06	−.02	.05	.31	.0001	.0056
Household furnishings	−.02	.01	−.10	−.08	−.10	.01	−.13	−.03	.01	.09	−.06	.30	−.0006	.0031
Health and recreation	.17	.00	−.11	−.08	−.15	−.12	−.07	.03	.04	.15	.07	.06	.0005	.0022
Home purchase price	.23	.05	−.11	−.13	−.05	−.01	.02	.00	−.04	.02	.06	.11	.0000	.0036
Home ownership	.27	.08	−.02	−.09	.08	.11	.08	.11	.05	.08	−.04	.02	.0007	.0031
Rent	.24	.21	.18	.16	.09	.11	.11	.15	.16	.23	.19	.16	−.0002	.0024
Fuel and utilities	.31	.14	−.01	−.06	−.05	.00	.10	−.02	.11	.14	.23	.31	.0000	.0043

NOTE.—Under the hypothesis that the true autocorrelations are equal to zero, the standard error of each estimated autocorrelation is approximately .06; $\bar{X}$ and $s(X)$ are the means and standard deviations of the indicated inflation rates and relative price changes; the autocorrelations ρ_τ are computed as regression coefficients.

Using (2) and (4) to substitute for $E(\tilde{\Delta}_{it} \mid \phi_{t-1})$ and $E(\tilde{\Delta}_t \mid \phi_{t-1})$, the expected relative price change can be expressed as

$$E(\tilde{\rho}_{it} \mid \phi_{t-1}) = E(\tilde{\eta}_{it} \mid \phi_{t-1}) - \sum_k w_k E(\tilde{\eta}_{kt} \mid \phi_{t-1}); \quad (12)$$

that is, the expected relative price change for good i is the differential part of its expected inflation rate, but the expected relative price change is also affected (inversely) by the differential expected inflation rates of other goods.

However, suppose the noncommon parts $E(\tilde{\eta}_{kt} \mid \phi_{t-1})$ of expected inflation rates are primarily seasonals that occur at different times of the year for different goods. Then, in any given month most of the $E(\tilde{\eta}_{kt} \mid \phi_{t-1})$ in (12) will be zero, and the nonzero $E(\tilde{\eta}_{kt} \mid \phi_{t-1})$ will be weighted by w_k. Thus, the weighted average of the $E(\tilde{\eta}_{kt} \mid \phi_{t-1})$ in (12) will usually be small, and the time series behavior of the expected relative price change for good i, $E(\tilde{\rho}_{it} \mid \phi_{t-1})$, will be determined primarily by $E(\tilde{\eta}_{it} \mid \phi_{t-1})$, the differential term in its own expected inflation rate. On the other hand, when equation (8) is valid, the estimated regression of the inflation rate for good i on the 1-month treasury bill rate will yield a coefficient close to 1.0 for the interest rate, in which case the time series behavior of the regression residuals is also determined by the behavior of $E(\tilde{\eta}_{it} \mid \phi_{t-1})$, the differential term in the expected inflation rate for good i.

The estimates of (8) in table 1 do in fact yield coefficients close to 1.0 for the interest rate, and the similarity between the autocorrelations of the relative price changes for good i in table 2 and the autocorrelations of its regression residuals in table 1 is consistent with the hypothesis that the behavior of the residuals reflect the differential term in the expected inflation rate for the good. In short, the estimates of (8) are consistent with the hypothesis that the interest rate reflects only the component of expected inflation rates which is common to all goods.

Direct Tests for Differential Seasonals

To provide some direct evidence about the differential seasonal expected inflation rates for the CPI components, table 3 contains estimates of the regression

$$\tilde{\Delta}_{it} = \sum_{j=1}^{12} \alpha_{ij} D_{jt} + \beta_i R_t + \tilde{\epsilon}_{it}, \quad (13)$$

where D_{jt} is a dummy variable equal to unity in month j and zero otherwise. The coefficients $\alpha_{ij}, j=1, \ldots 12$, allow different expected inflation rates for good i in different months of the year. We do not propose (13) as the "true" model for the seasonal behavior of prices; rather, the estimated regressions in table 3 are intended to provide

TABLE 3 Tests for Seasonality in Expected Inflation Rates, 1/53–7/71 and 1/75–12/77, $N = 259$

$$(\Delta_{it} = \beta_i R_t + \sum_{j=1}^{12} \alpha_{ij} D_{jt} + \epsilon_{it})$$

Index	β	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}	$\bar{R}^2$	$S(\epsilon_i)$	ρ_1	ρ_2	ρ_3	ρ_{12}	F-seasons*
		Seasonal Intercept Coefficients × 100																		
CPI	1.14	−.20	−.17	−.15	−.10	−.09	−.23	.04	.08	−.10	−.05	−.07	−.18	.46	.0019	.17	.21	.00	.01	5.86
	(.07)	(.05)	(.05)	(.05)	(.05)	(.05)	(.05)	(.05)	(.05)	(.05)	(.05)	(.05)	(.05)							
Food	1.14	.01	−.13	−.57	−.50	−.48	−.49	.43	.50	−.07	−.03	−.20	−.26	.30	.0052	.20	.08	−.13	−.12	9.63
	(.21)	(.13)	(.13)	(.13)	(.13)	(.13)	(.13)	(.13)	(.13)	(.13)	(.13)	(.13)	(.13)							
Apparel	.97	−1.16	−.28	−.03	.18	.74	−.12	−.39	−.20	.07	−.09	.07	−.02	.70	.0028	.09	−.17	−.10	.48	50.67
	(.11)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)							
Transportation	.99	−.17	−.47	.33	.53	−.30	−.04	.04	.06	−.02	−.01	−.05	−.29	.18	.0056	.05	.12	.07	.14	4.65
	(.22)	(.14)	(.14)	(.14)	(.14)	(.14)	(.14)	(.14)	(.14)	(.14)	(.14)	(.14)	(.14)							
Household furnishings	1.12	−.40	−.17	−.14	−.14	.12	−.37	−.29	−.07	−.27	−.17	−.05	.10	.47	.0023	.15	.14	.09	.19	10.81
	(.09)	(.06)	(.06)	(.06)	(.06)	(.06)	(.06)	(.06)	(.06)	(.06)	(.06)	(.06)	(.06)							
Health and recreation	1.00	.01	−.07	.00	−.01	.02	−.04	.04	−.03	−.07	.05	.03	−.04	.37	.0017	.19	.27	.14	.14	1.21
	(.07)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)							
Home purchase price	1.45	−.18	−.17	−.18	−.20	−.21	−.14	−.09	−.21	−.16	−.27	−.26	−.28	.24	.0034	.33	.15	−.03	.09	1.11
	(.14)	(.08)	(.08)	(.09)	(.09)	(.09)	(.09)	(.08)	(.08)	(.08)	(.08)	(.08)	(.08)							
Home ownership	1.63	−.21	−.15	−.19	−.20	−.18	−.06	−.13	−.07	−.12	−.23	−.21	−.28	.37	.0029	.35	.07	−.04	.05	1.52
	(.12)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)							
Rent	.68	−.02	.06	.01	.06	.01	.05	−.03	.00	−.01	.01	−.03	.00	.15	.0016	.53	.56	.49	.26	.34
	(.07)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)							
Fuel and utilities	.99	.05	.09	.12	−.01	.19	−.11	−.07	−.22	−.38	−.22	.03	−.12	.17	.0040	.27	.22	.17	.24	3.68
	(.16)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)							

NOTE.—The coefficient of determination, $\bar{R}^2$, is adjusted for degrees of freedom; $S(\epsilon_i)$ is the standard error of the regression residuals; and ρ_τ is the estimated residual autocorrelation at lag τ. Standard errors of the estimated regression coefficients are shown in parentheses.

*F-statistic for the hypothesis that the monthly intercepts are all equal ($H: \alpha_1 = \alpha_2 = \ldots = \alpha_{12}$), which has an F-distribution with 11 and 210 degrees of freedom.

some corroborative evidence for the existence of differential seasonal expected inflation rates.

The estimates of the coefficients of the seasonal dummy variables in table 3 indicate that there is substantial seasonal variation of expected inflation rates for food, apparel, transportation, household furnishings, and fuel and utilities. For each of these components, an F-test suggests low probability for the hypothesis that all the monthly intercepts are equal. Moreover, the seasonal patterns are different for different components. For example, there are large negative inflation seasonals for apparel in January and July, probably reflecting end-of-season sales. On the other hand, food prices fall (relatively) from February to June and rise from June to August, on average. It also seems that May is a month of positive inflation seasonals for apparel, household furnishings, and fuel and utilities.

Even though we do not claim that (13) is a complete model, the seasonal intercepts in table 3 seem to provide a good approximation to the seasonal behavior of expected inflation rates. The seasonal autocorrelations, ρ_{12}, of the regression residuals are substantially lower in table 3 than table 1. In fact, only the residuals for apparel show substantial autocorrelation at the seasonal lag when the regression intercept is allowed to vary across months.

Introducing seasonal dummy variables into the regression has little effect on the estimates of the coefficient of the interest rate. The estimates of β_i in table 3 are close to those in table 1. This is consistent with our model's hypothesis that the interest rate responds only to the common component of expected inflation rates and ignores the differential seasonals in the expected inflation rates of different goods. Thus, the results in table 3 seem to support the model proposed in (8) with the seasonal dummies in table 3 proxying for the noncommon variation in expected inflation rates, $E(\tilde{\eta}_{it}|\phi_{t-1})$, in (8). The proposition that these differential seasonals in expected inflation rates reflect differential costs in providing different goods to the market at different times of the year then provides a rationale for why the market might appropriately overlook such predictable variation in inflation rates when it sets interest rates.

Results for the Aggregate CPI Inflation Rate

If (7) is used to substitute for K_t in (3), the expression for the overall inflation rate becomes

$$\tilde{\Delta}_t = -E(\tilde{r}) + R_t + \sum_i w_i E(\tilde{\eta}_{it}|\phi_{t-1}) + \tilde{\epsilon}_t. \tag{14}$$

Since the hypothesis of (7) is that the interest rate only responds to the common part of expected inflation rates, R_t should be independent of the weighted average of the $E(\tilde{\eta}_{it}|\phi_{t-1})$, which implies that the estimated regression of $\tilde{\Delta}_t$ on R_t yields a slope coefficient for R_t equal to 1.0. The evidence in table 1 is consistent with this hypothesis.

If the $E(\tilde{\eta}_{it}|\phi_{t-1})$ in (14) are primarily differential seasonals in the inflation rates of different goods, they induce a variety of seasonals in the CPI inflation rate and in the residuals from the regression of the CPI inflation rate on the interest rate. In terms of (14), in a given month some of the $E(\tilde{\eta}_{it}|\phi_{t-1})$ are nonzero as a consequence of seasonals in the prices of the relevant goods, but most of the $E(\tilde{\eta}_{it}|\phi_{t-1})$ will be close to zero, and the commodities having substantial nonzero $E(\tilde{\eta}_{it}|\phi_{t-1})$ will be different for different months. One consequence is a substantial (0.18) autocorrelation at the seasonal lag 12 in the residuals from the regression of the CPI inflation rate, $\tilde{\Delta}_t$, on the interest rate, R_t, in table 1.

However, the seasonal dummy model (13) shows better how the differential seasonals in the inflation rates of different goods induce a complicated pattern of seasonals in the overall CPI. When (13) is applied to the CPI, the seasonal intercepts in the regression of the CPI inflation rate on the interest rate are just weighted averages of the corresponding intercepts for the components. Hence, a mixture of seasonals results when the components are combined into the overall CPI. The estimates of the seasonal intercepts for the CPI regression in table 3 reflect these combined differential seasonals, and the F-test easily rejects the hypothesis that the seasonal intercepts are equal across months. Moreover, the autocorrelation at lag 12 in the residuals for the CPI regression in table 3 is only 0.01, so the seasonal dummies successfully absorb the substantial seasonal autocorrelation observed in the residuals from the simple regression of the CPI inflation rate on the interest rate in table 1.

Since there is a part of the overall expected CPI inflation rate which is not reflected in the interest rate, the expected real return on treasury bills, $R_t - E(\tilde{\Delta}_t|\phi_{t-1})$, is not constant through time. The expected number of units of the CPI bundle which can be purchased with the return on a treasury bill varies inversely with $\sum_i w_i E(\tilde{\eta}_{it}|\phi_{t-1})$, the part of the overall expected inflation rate which does not show up in the return on the bill. Alternatively, in the context of our model, the term

$$\sum_i w_i E(\tilde{\eta}_{it}|\phi_{t-1})$$

results from seasonals in the costs of providing goods to the market at different times of the year and so might properly be interpreted as reflecting changes in the composition of the CPI consumption bundle. For example, an apple purchased in October is just an apple, whereas an apple purchased in March is the October apple plus several months of storage. However, the costs of storage services show up in the CPI as part of the price of an apple.

There is a substantial empirical literature on the constancy of the expected real return to treasury bills during the 1953–71 period (see, for example, Fama [1975, 1976, 1977], Hess and Bicksler [1975], Carlson [1977], Joines [1977], and Nelson and Schwert [1977]). The tests in table 3 provide additional direct evidence on significant seasonality in the expected real returns to treasury bills, given that one insists on measuring real returns in a way which does not reflect the varying costs of producing or storing the CPI consumption bundle throughout the year. However, it is more important to keep in mind that our evidence on seasonality is consistent with a full equilibrium model in which markets equate the risk-adjusted expected returns to production and to holding financial instruments.

Results for Longer Measurement Intervals

The model can be applied to inflation and interest rates measured over intervals other than a month. Table 4 summarizes estimates of the regressions of 3- and 6-month inflation rates of the CPI and its components on 3- and 6-month treasury bill rates. As in the monthly tests, the interest rates are ex ante in the sense that they are set in the market at the beginning of the 3- and 6-month period used to measure the corresponding ex post inflation rates.

Again, except for rent, home ownership, and home purchase price, the estimated regression coefficients for the interest rate in table 4 are within 2 and, more generally, within 1 SE of unity. This is consistent with the proposition that the 3- and 6-month treasury bill rates, like the 1-month rate, are tracking variation in expected inflation rates which is common to all goods.

For most of the series, the fourth-order residual autocorrelations in the regressions of quarterly inflation rates on the 3-month treasury bill rate are large. These autocorrelations correspond to the annual seasonals observed at the twelfth lag in the monthly regressions of table 1. However, for many of the series, including the CPI itself, the regressions of semiannual inflation rates on 6-month bill rates produce much less evidence of residual autocorrelation at the second order or seasonal lag. This is not surprising. The increase in variance that comes when one goes from monthly to quarterly or semiannual inflation rates can make seasonals that have short duration less noticeable. Moreover, seasonals tend to disappear in 6-month inflation rates when the inflation rates of intervening months or quarters have offsetting seasonals.

Some Comments on Troublesome Results

There are four series that do not conform well to the hypotheses of our model: rent, home ownership, home purchase price, and, to a lesser extent, fuel and utilities. The aberrant behavior of the rent component is traceable to lags built into the process by which this series is constructed. The rent index is based on contract rents for a fixed sample of

TABLE 4 **Regressions of Quarterly and Semiannual Inflation Rates on Three- and Six-Month Treasury Bill Rates**
($\Delta_{it} = \alpha_i + \beta_i R_t + \epsilon_{it}$)

A. Quarterly Inflation Rates and Treasury Bill Rates, 1/53–6/71 and 1/75–12/77 (N = 86)

Index	α_i	β_i	$\bar{R}^2$	$S(\epsilon_i)$	ρ_1	ρ_2	ρ_3	ρ_4
CPI	−.0029 (.0011)	1.05 (.11)	.52	.0042	.13	.07	.15	.22
Food	−.0029 (.0032)	.94 (.31)	.09	.0119	−.10	−.29	.07	.10
Apparel	−.0021 (.0018)	.80 (.18)	.19	.0068	−.06	−.24	−.03	.69
Transportation	−.0027 (.0029)	1.08 (.28)	.14	.0109	.02	.01	.11	.38
Household furnishings	−.0058 (.0012)	1.16 (.11)	.55	.0044	.31	.15	.20	.14
Health and recreation	.0000 (.0009)	.91 (.09)	.55	.0034	.35	.25	.20	.31
Home purchase price	−.0062 (.0020)	1.41 (.20)	.36	.0077	.16	−.04	−.04	.18
Home ownership	−.0050 (.0018)	1.52 (.17)	.47	.0067	.12	.07	.06	.10
Rent	.0014 (.0011)	.53 (.10)	.23	.0040	.75	.55	.40	.45
Fuel and utilities	−.0020 (.0024)	.97 (.23)	.16	.0090	.32	.36	.25	.56

NOTE.—The coefficient of determination, $\bar{R}^2$, is adjusted for degrees of freedom; $S(\epsilon_i)$ is the standard error of the regression residuals; and ρ_τ is the estimated residual autocorrelation at lag τ. Standard errors of the estimated regression coefficients are shown in parentheses. The data used in the regressions are for nonoverlapping 3- or 6-month intervals.

apartments. The rent on a given apartment is sampled every 6 months, with different apartments staggered across months and with unsampled rents assumed to be unchanged. Unless there is a change in tenants, most rental contracts are only renegotiated annually. Thus, when there is a change in the rent on a given apartment, it usually shows up in the rental index somewhat later, and it usually reflects changes in the rental market (that is, changes in rents on similar apartments) for a 1-year period. One could argue that the rent index, as constructed, gives a reasonably accurate picture of the experience of the rental population. However, it does not provide good estimates of the inflation rate in the rental market, that is, the rents one would face entering the market in month t vis-à-vis entering in month $t-1$.[4]

Because of the lags in the collection process for the rent series, measured rental inflation rates are substantially out of date. One man-

4. Other consumer purchases that are generally made on a long-term basis are not treated by the BLS in the same way as rents. For example, in measuring prices for autos and other consumer durables, the BLS uses the prices at which new transactions take place each month.

B. Semiannual Inflation Rates and Treasury Bill Rates,* 7/59–6/71 and 1/75–12/77 ($N = 30$)

Index	α_i	β_i	$\bar{R}^2$	$S(\epsilon_i)$	ρ_1	ρ_2
CPI	−.0103	1.16	.65	.0064	.12	.00
	(.0039)	(.16)				
Food	−.0060	.90	.15	.0147	−.27	−.24
	(.0089)	(.36)				
Apparel	−.0019	.68	.16	.0108	−.21	.55
	(.0066)	(.26)				
Transportation	−.0125	1.25	.29	.0143	.08	.24
	(.0087)	(.35)				
Household furnishings	−.0155	1.25	.60	.0077	.32	.21
	(.0046)	(.19)				
Health and recreation	−.0041	.99	.62	.0058	.39	.26
	(.0035)	(.14)				
Home purchase price	−.0213	1.66	.49	.0127	−.06	.12
	(.0077)	(.31)				
Home ownership	−.0208	1.82	.62	.0108	.13	−.12
	(.0065)	(.26)				
Rent	−.0062	.84	.49	.0064	.54	.51
	(.0038)	(.16)				
Fuel and utilities	−.0147	1.30	.25	.0161	.48	.60
	(.0097)	(.39)				

*Continuous data on 6-month bills start in March 1959.

ifestation of the problem is estimated coefficients for the interest rate in the inflation-interest rate regressions for rent that are much less than 1.0. Another manifestation of the problem is autocorrelations of relative rental price changes in part B of table 2 that are positive and large at all lags. All of this is to be expected, given that the current monthly measured rental inflation rate contains parts of the true rental inflation rates for up to 18 preceding months.

A similar "lag effect" might also show up in the results for the fuel and utilities component. Table 5 shows a breakdown of the CPI with some detail on the subcomponents of the major components that we study here, along with the weights that have been assigned to components since the January 1964 revision of the CPI. We can see from the table that the fuel and utilities component depends on utility rates (gas, telephone, electric, and water) regulated by government agencies. From the persistent high autocorrelations of the relative price changes of this component in table 2 and from the likewise high autocorrelations of its regression residuals in tables 1 and 4, we might conclude that the relevant regulatory bodies react with different and variable lags in adjusting to variation in inflation conditions.

The home ownership series presents more difficult problems. Ideally, this series should measure the equivalent rental value of an owner-occupied home, and it is not clear that the subcomponents of the series, shown in table 5, adequately capture this concept. Moreover,

TABLE 5 The Components of the Consumer Price Index

Component	1964 Percent Weight		
Food:			22.43
Food at home:		17.89	
Cereals and bakery products	2.45		
Meats, poultry, and fish	5.63		
Dairy products	2.80		
Fruits and vegetables	3.02		
Other food	3.99		
Food away from home		4.54	
Shelter:			20.15
Rent		5.50	
Hotels and motels		.38	
Home ownership:		14.27	
Home purchase price	6.28		
Mortgage interest	2.83		
Real estate taxes	1.72		
Property insurance	.41		
Maintenance	3.03		
Fuel and utilities:			5.26
Fuel oil and coal		.73	
Gas and electricity		2.71	
Telephone and water		1.82	
Household furnishings			7.82

Component	1964 Percent Weight		
Apparel			10.63
Transportation:			13.88
Auto purchase		5.02	
Gas, oil, and parts		4.00	
Auto repairs		.98	
Other auto expenses		2.64	
Public transportation		1.24	
Health and recreation			19.45
Medical care:		5.70	
Drugs	1.14		
Professional services	2.59		
Hospital services	.36		
Health insurance	1.61		
Personal care		2.75	
Recreational goods		2.78	
Recreational services		1.58	
Reading and education		1.58	
Other goods and services:		5.06	
Tobacco products	1.89		
Alcoholic beverages	2.64		
Personal expenses	.53		
Miscellaneous			.38

SOURCE.—Condensed from appendix table 9 of U.S. Department of Labor, Bureau of Labor Statistics, Bulletin no. 1517, "The Consumer Price Index: History and Techniques" (1966). The weights shown for individual components are those put into effect with the revision of the CPI in January 1964. The weights are based on consumer expenditure surveys, and they are held constant between revisions of the index. The next major revision occurs in January 1978.

there are problems in the way the home purchase price subcomponent of home ownership is constructed. The home purchase price index is based on price per square foot of newly insured FHA housing. In addition to calculating on a per square foot basis, the BLS tries to control for other quality variables such as age, region, number of bathrooms, etc., all of which is desirable for the purpose of measuring inflation rates. However, the index has some notable disadvantages. It only exists as a 3-month moving average. The date on any particular home's price is the insurance date, which usually follows the date when the price was negotiated. A communication from the BLS indicates that the data for the most recent month are already 1 month old when they are obtained from the Department of Housing and Urban Development. The moving average and lags built into the calculation of the home purchase price series may explain the relatively large first- and second-order autocorrelations of its regression residuals in table 1, which also show up in the results for its parent series, home ownership. On the other hand, these anomalies in the data do not explain the large estimated regression coefficients for the interest rate that are obtained for home ownership and home purchase price in tables 1 and 4.

We have also estimated the regressions in tables 1 and 4 using only data for the precontrols period, January 1953 to July 1971. In these results the estimated regressions of home purchase price inflation rates on treasury bill rates yield coefficients for the interest rate much closer to unity (e.g., 1.18 in the monthly data) than those in tables 1 and 4. But for the home ownership inflation rates, the regression coefficients for the interest rates estimated in the precontrols period are much like those for the combined pre- and postcontrol periods used in tables 1 and 4. On the other hand, for the fuel and utilities inflation rates, the estimated regression coefficients for the treasury bill rates for the precontrols period are much further below unity (e.g., 0.36 in the monthly data) than those in tables 1 and 4, all of which confirms the anomalous behavior of these series.

However, fuel and utilities, rent, home ownership, and home purchase price, which together account for 25% of the CPI, are the only series which cause problems for our model. For all of the other series the model works well; that is, for the precontrols period alone as for the combined pre- and postcontrols period shown in tables 1 and 4, we find regression coefficients close to 1.0 for the interest rate in estimated inflation-interest rate regressions, and residual autocorrelations that seem largely to be the consequence of differential seasonals in expected inflation rates.[5] In short, the generalizations we have developed about the behavior of inflation rates and the nature of inflation–interest

5. Similar results are also obtained when the data are split into the two subperiods preceding and following the January 1964 revision of the CPI.

rate relationships cover about 75% of the goods in the CPI, and the aberrant behavior of much of the remaining 25%, specifically, rent, fuel and utilities, and home purchase price, seems to have reasonable explanations.

III. The Common Variation in Unexpected Inflation Rates

The regressions of inflation rates on interest rates in tables 1, 3, and 4 are consistent with the proposition that, aside from differential seasonals, variation through time in expected inflation rates is common to the various components of the CPI. An attractive economic interpretation is that resources are allocated to the production of different goods so as to equate expected inflation rates across goods.

It is also interesting to measure the extent to which there is covariation in the unexpected parts of the inflation rates of different goods. For example, in an idealized world where resources could be reallocated instantaneously and costlessly to the production of different goods, one would expect equalization of ex post returns to the production of different goods as well as equalization of ex ante expected returns. Generally this would imply a large degree of similarity in the unanticipated as well as in the anticipated parts of the inflation rates of different goods.

Consider the multiple regression of the inflation rate $\tilde{\Delta}_{it}$ for a component of the CPI on the interest rate, R_t, and on $\tilde{\Delta}_t - R_t$, the deviation of the CPI inflation rate from the interest rate,

$$\tilde{\Delta}_{it} = \alpha_i + \beta_i R_t + \gamma_i(\tilde{\Delta}_t - R_t) + \tilde{\epsilon}_{it}. \tag{15}$$

A slope coefficient close to 1.0 in the regression of the CPI inflation rate $\tilde{\Delta}_t$ on R_t implies that R_t and $\tilde{\Delta}_t - R_t$ are close to uncorrelated. Thus, the coefficient of R_t in the multiple regression of $\tilde{\Delta}_{it}$ on R_t and $\tilde{\Delta}_t - R_t$ will be the same as in the simple regression of $\tilde{\Delta}_{it}$ on R_t. We can again interpret the coefficient of the interest rate as measuring the common movement in the expected inflation rates of different goods. The coefficient of $\tilde{\Delta}_t - R_t$ in the multiple regression then tells us how the inflation rate for component i, $\tilde{\Delta}_{it}$, varies, on average, with the unanticipated part of the CPI inflation rate. The presumption, of course, is that $\tilde{\Delta}_t - R_t$ summarizes general movement in unanticipated inflation rates.

Monthly Results

The estimated multiple regressions of the inflation rates of the CPI components on R_t and $\tilde{\Delta}_t - R_t$ for monthly data are summarized in table 6. The coefficients of the interest rate R_t are similar to those obtained in the simple regressions of the monthly $\tilde{\Delta}_{it}$ on the 1-month treasury bill rate in table 1. Again, except for the usual maverick series,

TABLE 6 **Regressions of Monthly Inflation Rates on the One Month Treasury Bill Rate and the Unexpected CPI Inflation Rate, 1/53–7/71 and 1/75–12/77, N = 259**
($\Delta_{it} = \alpha_i + \beta_i R_t + \gamma_i(\Delta_t - R_t) + \epsilon_{it}$)

Index	α_i	β_i	γ_i	$\bar{R}^2$	$S(\epsilon_i)$	ρ_1	ρ_2	ρ_3	ρ_{12}
Food	.0009	.79	2.18	.56	.0041	.31	−.01	−.16	.36
	(.0006)	(.19)	(.13)						
Apparel	−.0005	.85	.38	.07	.0050	.17	−.21	−.25	.81
	(.0007)	(.23)	(.15)						
Transportation	.0003	.96	1.12	.18	.0056	.01	.02	.06	.33
	(.0008)	(.26)	(.17)						
Household furnishings	−.0015	1.16	.22	.27	.0027	−.02	−.01	.03	.43
	(.0004)	(.13)	(.08)						
Health and recreation	.0003	.93	.26	.42	.0016	.16	.15	.03	.14
	(.0002)	(.07)	(.05)						
Home purchase price	−.0015	1.41	.42	.28	.0033	.30	.11	−.07	.12
	(.0005)	(.16)	(.10)						
Home ownership	−.0013	1.59	.43	.41	.0028	.32	.05	−.06	.05
	(.0004)	(.13)	(.09)						
Rent	.0007	.53	.18	.21	.0016	.43	.48	.41	.24
	(.0002)	(.07)	(.05)						
Fuel and utilities	−.0001	.87	.41	.11	.0041	.31	.19	.08	.34
	(.0006)	(.19)	(.13)						

NOTE.—The coefficient of determination, $\bar{R}^2$, is adjusted for degrees of freedom; $S(\epsilon_i)$ is the standard error of the regression residuals; and ρ_τ is the estimated residual autocorrelation at lag τ. Standard errors of the estimated regression coefficients are shown in parentheses.

the estimated regression coefficients for the interest rate in table 6 are close to 1.0. Movements in the interest rate track common movement in expected inflation rates.

The estimated regression coefficients for $\tilde{\Delta}_t - R_t$ in table 6 tell a different story. The only component of the CPI whose inflation rate seems on average to vary in one-to-one correspondence with $\tilde{\Delta}_t - R_t$ is transportation. For most other components, the coefficients of $\tilde{\Delta}_t - R_t$ are much less than 1.0. In some cases, specifically fuel, rent, home ownership, and home purchase price, the small regression coefficients for $\tilde{\Delta}_t - R_t$ might be another manifestation of lags in measured inflation rates that result from built-in lags in price collection or in the adjustment of regulated prices to market conditions. However, the small regression coefficients for apparel and household furnishings cannot be explained in these terms. In contrast, the inflation rate for food seems superrelated to the overall unanticipated inflation rate; on average, a

1% change in $\tilde{\Delta}_t - R_t$ is associated with a change of more than 2% in the food inflation rate.

There is another way to look at the results in table 6. If we multiply each component's weight in the CPI through the multiple regression of the component's inflation rate on R_t and $\Delta_t - R_t$ and then sum across the CPI components, both the left- and right-hand sides of the resulting expression must be equal to the CPI inflation rate:

$$\tilde{\Delta}_t = \sum_i w_i \tilde{\Delta}_{it} = \sum_i w_i \alpha_i + \sum_i w_i \beta_i R_t + \sum_i w_i \gamma_i (\tilde{\Delta}_t - R_t) + \sum_i w_i \tilde{\epsilon}_{it}. \quad (16)$$

Thus, the product of a component's weight in the CPI with its regression coefficient for the interest rate can be interpreted as the contribution of the component to the variation in the expected inflation rate of the CPI. The component's weight times its regression coefficient for $\tilde{\Delta}_t - R_t$ measures the average contribution of the component to the variation in the unexpected part of the CPI inflation rate.[6]

The fact that the CPI components have estimated regression coefficients for the interest rate that are close to 1.0 makes this breakdown of the expected inflation rate for the CPI into contributions by individual components somewhat uninteresting. More interesting results are obtained when the analysis is applied to the unexpected part of the CPI inflation rate. The regression coefficients for $\tilde{\Delta}_t - R_t$ vary substantially across components, so that a component's average contribution to the unexpected part of the CPI inflation rate does not correspond so nicely to its weight in the CPI. For example, food is .2243 of the CPI, but food has such a large (2.18) regression coefficient for $\tilde{\Delta}_t - R_t$ that on average it accounts for almost half of the unexpected monthly CPI inflation rate. On the other hand, the weight of health and recreation in the CPI, .1945, is similar to that for food, but health and recreation has a low (0.26) regression coefficient for $\tilde{\Delta}_t - R_t$, and on average it accounts for only about 5% of the unexpected monthly CPI inflation rate. Because of their small regression coefficients for $\tilde{\Delta}_t - R_t$, fuel, apparel, household furnishings, home ownership, and rent likewise on average contribute to $\tilde{\Delta}_t - R_t$ much less than in proportion to their weight in the CPI. Only transportation makes an average contribution to $\tilde{\Delta}_t - R_t$ which is about equivalent to

6. If the weights of components in the CPI are constant through time, and if R_t and $\tilde{\Delta}_t - R_t$ are uncorrelated, then it can be shown that in the regressions of the inflation rates of the components on R_t and $\tilde{\Delta}_t - R_t$, the weighted averages of the regression coefficients for both R_t and $\tilde{\Delta}_t - R_t$ are equal to 1.0, the weighted average of the intercepts is zero, and the weighted average of the residuals for any given t is zero. Although R_t and $\tilde{\Delta}_t - R_t$ are very nearly uncorrelated, the weights of the components in the CPI are not literally constant through time. Most important is the change in weights introduced with the 1964 revision of the CPI. This denies complete precision to the statements of the text, but they are nevertheless useful approximations.

its weight, .1388, in the CPI; and next to food, transportation makes the biggest contribution to the unexpected part of the CPI inflation rate.

Finally, when R_t and $\tilde{\Delta}_t - R_t$ are uncorrelated, the regression coefficients γ_i for $\tilde{\Delta}_t - R_t$ in (15) have yet another interesting interpretation. The variance of $\tilde{\Delta}_t - R_t$ can be expressed as

$$\sigma^2(\tilde{\Delta}_t - R_t) = \sum_i \sum_j w_i w_j \text{cov}(\tilde{\Delta}_{it} - R_t, \tilde{\Delta}_{jt} - R_t)$$
$$= \sum_i w_i \text{cov}(\tilde{\Delta}_{it} - R_t, \tilde{\Delta}_t - R_t).$$

However, when R_t and $\tilde{\Delta}_t - R_t$ are uncorrelated, $\text{cov}(\tilde{\Delta}_{it} - R_t, \tilde{\Delta}_t - R_t) = \text{cov}(\tilde{\Delta}_{it}, \tilde{\Delta}_t - R_t)$, from which it follows that

$$w_i \gamma_i = w_i \frac{\text{cov}(\tilde{\Delta}_{it}, \tilde{\Delta}_t - R_t)}{\sigma^2(\tilde{\Delta}_t - R_t)}$$

measures the proportional contribution of good i to the variance of the overall unexpected inflation rate, $\tilde{\Delta}_t - R_t$.

Results for Quarterly and Semiannual Data

Table 7 summarizes regressions of the component inflation rates, $\tilde{\Delta}_{it}$, on R_t and $\tilde{\Delta}_t - R_t$ for quarterly and semiannual versions of the variables. To maximize the comparability of the results, all the regressions are limited to the period beginning in July 1959 for which continuous data on 6-month bill returns are available.

The estimated regression coefficients for $\tilde{\Delta}_t - R_t$ seem to move closer together and, more particularly, toward 1.0 as one goes from the regressions for monthly data in table 6 to those for quarterly and then semiannual data in table 7. For eight of the nine components, the estimated coefficients for $\tilde{\Delta}_t - R_t$ are closer to 1.0 in the quarterly and semiannual regressions than in the monthly regressions, and for seven of the nine components the coefficients estimated from semiannual data are closer to 1.0 than those estimated from quarterly data. For food, the estimated coefficient for $\tilde{\Delta}_t - R_t$ descends toward 1.0 in the quarterly and semiannual results from a value over 2.0 in the monthly data, while for household furnishings, home ownership, health and recreation, and home purchase price the estimated coefficients rise toward 1.0 in the quarterly and semiannual data from values less than 0.5 in the monthly data.

We expect some component inflation rates to vary more in line with the CPI inflation rate for longer measurement intervals simply because the built-in lags of these series vis-à-vis the CPI become less important for longer measurement intervals. Likewise, some of the movement toward 1.0 of the coefficients of $\tilde{\Delta}_t - R_t$ might reflect common short-term movement in expected inflation rates which tends to be pushed into $\tilde{\Delta}_t - R_t$ as one lengthens the interval over which the inflation and

TABLE 7 **Regressions of Inflation Rates on the Treasury Bill Rate and the Unexpected CPI Inflation Rate**
($\Delta_{it} = \alpha_i + \beta_i R_t + \gamma_i(\Delta_t - R_t) + \epsilon_{it}$)

Index	α_i	β_i	γ_i	$\bar{R}^2$	$S(\epsilon_i)$	ρ_1	ρ_2	ρ_3	ρ_4
	A. Quarterly Data: 7/59–6/71 and 1/75–12/77 (N = 60)								
Food	.0069 (.0032)	.48 (.26)	1.80 (.22)	.55	.0070	−.01	.06	.07	.01
Apparel	.0023 (.0031)	.59 (.25)	.72 (.22)	.22	.0068	.04	−.18	−.08	.59
Transportation	.0015 (.0042)	.96 (.35)	1.40 (.30)	.36	.0093	−.01	−.01	−.02	.20
Household furnishings	−.0055 (.0019)	1.22 (.16)	.45 (.14)	.56	.0043	.19	.02	.14	.04
Health and recreation	.0001 (.0014)	.97 (.12)	.44 (.10)	.62	.0031	.04	.12	.08	.18
Home purchase price	−.0075 (.0034)	1.64 (.28)	.72 (.24)	.45	.0074	.07	−.10	−.16	.15
Home ownership	−.0084 (.0029)	1.89 (.24)	.63 (.20)	.58	.0064	−.07	.18	−.02	.07
Rent	−.0014 (.0013)	.83 (.11)	.42 (.09)	.61	.0029	.50	.35	.39	.38
Fuel and utilities	−.0048 (.0041)	1.30 (.34)	.66 (.29)	.26	.0091	.27	.25	.34	.43
CPI	−.0044 (.0018)	1.17 (.15)	...	.50	.0041	.13	.15	.06	.12

	B. Semiannual Data: 7/59–6/71 and 1/75–12/77 (N = 30)								
Food	.0103	.64	1.57	.53	.0110	−.22	.12	. . .	. . .
	(.0074)	(.27)	(.32)						
Apparel	.0028	.60	.46	.19	.0106	−.25	.53	. . .	. . .
	(.0072)	(.26)	(.31)						
Transportation	.0003	1.05	1.23	.49	.0122	.16	−.01	. . .	. . .
	(.0083)	(.30)	(.36)						
Household furnishings	−.0081	1.13	.72	.73	.0063	.04	−.05	. . .	. . .
	(.0043)	(.16)	(.19)						
Health and recreation	.0022	.90	.61	.79	.0044	.04	.01	. . .	. . .
	(.0030)	(.11)	(.13)						
Home purchase price	−.0113	1.50	.96	.59	.0113	−.25	.23	. . .	. . .
	(.0076)	(.28)	(.33)						
Home ownership	−.0117	1.67	.89	.71	.0093	.24	.08	. . .	. . .
	(.0063)	(.23)	(.28)						
Rent	.0010	.72	.70	.73	.0046	.32	.33	. . .	. . .
	(.0031)	(.11)	(.14)						
Fuel and utilities	−.0002	1.07	1.40	.47	.0137	.31	.57	. . .	. . .
	(.0092)	(.34)	(.40)						
CPI	−.0103	1.16	. . .	.65	.0064	.12	.00	. . .	. . .
	(.0039)	(.16)							

NOTE.—The coefficient of determination $\bar{R}^2$, is adjusted for degrees of freedom; $S(\epsilon_i)$ is the standard error of the regression residuals; and ρ_τ is the estimated residual autocorrelation at lag τ. Standard errors of the estimated regression coefficients are shown in parentheses. The data used in the regressions are for nonoverlapping 3- or 6-month intervals.

interest rates are measured. For example, the semiannual unexpected inflation rate includes the five changes in monthly expected inflation rates which occur within the 6-month period. Such short-term changes in expected inflation rates are less likely to affect monthly unexpected inflation rates.

Finally, there is also the important possibility that some of the increasing similarity in the behavior of the coefficients of the unexpected inflation rate reflects a reallocation of resources in response to unanticipated shifts in demand or supply conditions for different products. Thus, the fact that individual component inflation rates have coefficients on R_t that are close to 1.0 might mean that on an ex ante basis resources are allocated to the production of different goods in such a way as to approximately equate expected inflation rates across goods. The equating of expected inflation rates is only approximate, however, since there are some short-term autocorrelations and annual seasonals in the residuals from the inflation-interest rate regressions. These autocorrelations might reflect costs of transferring resources quickly or temporarily in order to equate expected inflation rates across goods. Ex post there are always surprises that cause realized inflation rates to differ across goods. One manifestation of this might be differences across components in the regression coefficients for the unexpected CPI inflation rate $\tilde{\Delta}_t - R_t$ obtained in the monthly data. On a longer-term basis, however, such differential price effects tend to wash out as resources are reallocated to equate ex post inflation rates across goods. Thus, on a longer-term basis the prices of different goods tend to move more similarly with the overall unexpected inflation rate.

IV. Further Evidence on the Behavior of Prices

We do not mean to push too hard on this line of interpretation. The presumption that long-term equilibrium in rates of return to different production activities implies equal inflation rates across goods implies other presumptions about conditions of production. One scenario includes (i) constant returns to scale, at least at the industry level, (ii) constant technologies or technologies that advance at the same rate across industries, and (iii) constant relative factor prices. If one or more pieces of this scenario do not hold, equilibrium may imply permanent changes in the relative prices of different goods. For example, given competitive markets for outputs and inputs, we would expect relative price declines for the products of industries that experience unusual increases in productivity and relative price increases in industries where the productivity of capital and labor advances at below average rates.

Means and standard deviations of monthly inflation rates and relative price changes are summarized in table 2. The mean relative price changes for most of the components seem close to zero; that is, their average inflation rates are similar to that of the CPI. However, there are important exceptions. Costs of home ownership and health and recreation have risen relative to average prices for all goods, while the relative prices of household furnishings and apparel have fallen. Because of the deviations of the average inflation rates for these components from the average rate for the CPI, the hypothesis that the differences among the average inflation rates for the components are chance sampling phenomena is easily rejected with a Hotelling T^2 test.

Perhaps the lower average inflation rate for the household furnishings component of the CPI reflects above-average technological advances in the production of consumer durables (appliances and furniture). Likewise, the above-average inflation rate for health and recreation might be due to some extent to below-average rates of productivity increase for the industries represented in this component, which includes several labor-intensive products like haircuts and medical and dental visits.

On the other hand, the above-average inflation rate for the home ownership component does not seem to be traceable to below-average rates of technological advance in the building industry. The home purchase price subcomponent (like the rent component) shows an average inflation rate quite similar to that of the CPI. Thus, the high average inflation rate of home ownership is due to its other subcomponents, real estate taxes, mortgage interest expense, and maintenance. An above-normal inflation rate for taxes may just reflect expanded public services to homeowners; in effect, the BLS has not properly controlled for quality change. And, of course, quality changes, which are difficult to measure precisely, probably produce some degree of spurious dispersion in the average inflation rates of the different components of the CPI.

The regression results in tables 6 and 7 support the conclusion that inflation rates of different goods behave more similarly when they are measured over longer intervals. However, these tables also show that there is substantial variation in relative price changes even in semiannual data. Consider the regression equation (15). If both β_i and γ_i are equal to one and the variance of the disturbance, $\tilde{\epsilon}_i$, is zero, the inflation rate of commodity i, $\tilde{\Delta}_{it}$, is perfectly correlated with the overall inflation rate, $\tilde{\Delta}_t$. If this is true for all commodities, there are no relative price changes. Even though the estimates of β_i and γ_i, the coefficients of R_t and $\tilde{\Delta}_t - R_t$, are close to unity for most components in part B of table 7, and even though coefficients of determination generally rise as one goes from the monthly results in table 6 to the quarterly and semiannual results in table 7, residual standard errors are always substantial. Thus, even for semiannual data, variability of relative price changes is an important part of the behavior of the money prices of the CPI components.

V. Conclusions

The expected inflation rates of different components of the CPI contain a term which is common to all goods, but there are also differentials in expected inflation rates, primarily annual seasonals that vary in timing and magnitude across goods. Since the CPI is a portfolio of its components, the differential seasonals of the components introduce a rich range of seasonals into the behavior of the CPI inflation rate.

In setting interest rates on treasury bills, the market appears to respond only to the common part of the expected inflation rates of different goods. Since the seasonals in inflation rates, including those in the CPI itself, seem to be due to differential seasonals for different goods, and since these seasonals are overlooked by the market in setting interest rates, we suggest that the seasonals might arise from real costs of providing different goods to the market at different times of the year, for example, storage costs which arise because production and demand for different goods do not conform to coincident seasonal patterns.

Although the wandering of expected inflation rates is largely common to all goods, on a short-term basis the unexpected parts of the inflation rates of different goods vary in quite dissimilar fashion. As one looks at unexpected inflation rates for longer differencing intervals, however, a noticeable tendency toward increased similarity of behavior is observed. Some of the dissimilarity in the behavior of short-term unexpected inflation rates is probably a mechanical consequence of differential lags in the reporting of inflation rates for different goods. However, it is also appealing to attribute part of the increasing similarity in the behavior of longer-term unexpected inflation rates to real market forces, that is, an eventual reallocation of resources in response to surprise shifts in the demands or supplies of different goods. Given the common term in the behavior of the expected inflation rates of different goods, we are then left with a view of the world in which the market allocates resources to equate ex ante (net of risk) expected returns from the production of different goods and then eventually makes the appropriate reallocations in response to ex post surprises.

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