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Inflation and Relative-Price Variability-A Model for an Open Economy Applied to Sweden

The relationship between inflation and relative-price variability is analyzed empirically in a multi-market, partial information equilibrium model, which incorporates raw materials on the supply side, open economy characteristics and allows different supply responses across markets. The hypothesis that the expected, as well as the unexpected, rate of inflation affects relative-price variability is put forward and tested. The empirical results are consistent with the view that inflation is non-neutral, in the sense that it affects relative prices, and it is also shown that raw material prices as well as foreign demand are important determinants of relative-price variability in the Swedish economy.

1. Introduction

In a dichotomized model where money is neutral, there is an independence between nominal and real variables. Relative prices are determined in the "real" sector and the general price level is determined in the monetary sector. Though this question has mostly been concerned with the neutrality of money,[1] the question of the relationship between the general price level and relative prices, or relative-price variability, has also been raised in this context [for a survey, see Cukierman (1984) or Marquez and Vining (1984)].

Several empirical and theoretical studies on the relationship between inflation and relative-price variability appeared in the mid-70s. Vining and Elwertowski (1976) discussed this relationship and their empirical study was based on the presumed independence between relative prices and the expected rate of inflation found in Lucas (1973). Apart from several empirical studies [see Jafl~ee and Kleiman (1977), Fischer (1981a, 1981b) and Blejer (1981)], this relationship was explicitly modeled by Parks (1978), Cukierman (1979),

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[1]Bordo *(1980)* and Hercovitz *(1981)* analyse the relationship between money and the variability of relative prices.

Cukierman and Wachtel *(1979)* and by Blejer and Leiderman *(1982)* for an open economy. As in the Phelps/Friedman expectations-augmented Phillips curve model [see Phelps *(1967)* and Friedman *(1968)]*, the former models allowed for a link between unanticipated nominal and real variables through agents' partial information.

A positive relationship between squared unanticipated inflation and the variance of relative-price changes is emphasized by Parks *(1978)*, between the variance of the general price level and the variance of relative prices by Cukierman and Wachtel *(1979)*, and between unanticipated money and the variance of relative prices by Hercovitz *(1981)*.

The neutrality of nominal variables was questioned by Keynes [see Keynes *(1930), p. 87]* and in Keynesian models there is an explicit relationship between nominal and real variables. But that can be found in a variety of models. In a model with price adjustment costs, price-setting firms would not change prices continuously, but at discrete intervals. Differences in adjustment costs between firms imply differences in the size and frequency of price changes, and an increase in the *expected* rate of inflation would increase the variability of relative-price changes [see Sheshinsky and Weiss *(1977), p. 301]*.

A more general concept of adjustment costs can be found in Okun's model of mixed auction and customer markets. The adjustment in prices to different kinds of shocks differs across markets. Hence, e. g., an oil-price shock would increase inflation, relative-price variability and unemployment in the Okun model [Okun *(1981)*, Ch. VI]. The same conclusions are reached in a similar framework by Weizsacker *(1977)* and Wachter and Williamson *(1978)*, who emphasize the dynamic changes in contract structure due to different kinds of shocks. These models imply a positive relationship between inflation and relative-price, and that price variability increases, due to gradual changes in contracts, as the core inflation rate increases.

Likewise, in the Scandinavian model of wage and price formation [see Edgren, Faxen and Odhner *(1973)* and Aukrust *(1970, 1977)]*, there is a positive relationship between relative-price change variability and the rate of inflation. In the Scandinavian model, based on fixed exchange rates, a constant functional distribution of income and a division of markets into a competitive and a sheltered sector, wage changes in the competitive sector are determined by changes in world market prices and by changes in labor productivity in that sector. Price changes in the sheltered sector are then determined as the sum of wage changes in the competitive sector and productivity changes in the sheltered sector. An increase in the variability of productivity changes across sectors would cause both inflation and relative-price variability to move in the same direction.[2]

The purpose of the present study is to examine empirically the proposed independence between expected inflation and the variability of relative-price changes. A model of relative-price vari ability for an open economy is constructed and tested empirically.

The paper is organized in the following way. Section 2 presents the model and Section 3 is assigned for the empirical estimations and results. Section 4 concludes.

2. The Model

The strategy is to construct a nested model where relative-price variability is affected by both unexpected and expected inflation. The model is an equilibrium model formulated for many markets. It is an extension of the model in Parks (1978).

Let p_{it} be the price of commodity i at time t and let P_t be the general price level. Letting D denote the logarithmic first difference we get

$$Dp_{it} - DP_t = (\log p_{it} - \log p_{it-1}) - (\log P_t - \log P_{t-1}), \quad i = 1, \ldots, n$$

as the percentage change in the relative price of commodity i at time t, where the log is the natural logarithm.

We define the variability of relative-price changes by the variance measure [on the properties of this measure, see Theil (1967), p. 155]

$$Vp_t = \sum_{i=1}^{n} w_{it}(Dp_{it} - DP_t)^2 , \qquad (1)$$

where w_{it} is the value share of commodity i at time t. DP_t, the rate of inflation, is defined by

[2] In this paper we assume that the causality is from inflation to relative-price variability. As shown e.g. in Fischer (1982) the causality question is ambiguous; there exist theories which imply causality in both directions. Weak empirical support for the exogeneity assumption made here can be found in Ashley (1981), who found direct Granger causality from inflation to relative-price variability for U. S. monthly data, but no direct feedback from relative-price variability to inflation. Similar studies for Sweden [see Assarsson (1984) Ch. 6] point in the same direction.

$$DP_t = \log P_t - \log P_{t-1} = \sum^{n} w_i DP_{it} .$$

Then we define supply and demand functions (q^s_{it} and q^d_{it}, respectively) for the market i at time t, i = 1, .. , n, as

$$\log q^s_{it} = \epsilon_i + \alpha_i \log (p_{it}/EP_t) + \beta_i \log (p_{it}/p_{rmt}) \qquad (2)$$

and

$$\log q^d_{it} = \gamma_i + \eta_i \log (p_{it}/P_t) + \omega_i \log (y^d_t/P_t)$$

$$+ \theta_i \log (p_{it}/PW_t) + \lambda_i \log (y^f_t/PW_t) ,$$

where EP_t is the expected price level at time t conditional on the information set h, to be defined later, p_{rmt} is the price of raw materials, t is time, y^d_t is the domestic level of money income, PW_t is the foreign price level and y^f_t is the foreign level of money income.

The supply function is based on a generalized Cobb-Douglas technology with a fixed capital stock. It is also based on a cleared labor market, where the equilibrium nominal wage depends on the expected price level. Hence, the (minimum) cost function of the firm depends on the expected price level, other input prices and the output level. These supply functions could be labelled deterministic Lucas type supply functions. The demand functions depend on domestic and foreign prices and income. For simplicity, all cross-price effects are ignored. These demand functions are homogenous of degree zero in income and prices but do not necessarily satisfy the adding-up restriction. α_i, β_i, ω_i and λ_i are expected to be positive and η_i and θ_i to be negative.

The model can be solved for the equilibrium relative-price changes by taking the logarithmic first differences of (2) and (3) and equating supply and demand. The solutions are

$$DP_{it} - DP_t = g_i^{-1}[-\alpha_i(DP_t - EDP_t) + \beta_i(Dp_{rmt} - DP_t)$$

$$+ \omega_i(Dy^d_t - DP_t) + \theta_i(DP_t - DPW_t)$$

$$+ \lambda_i(Dy^f_t - DPW_t)] \qquad (4)$$

where $g_i = (\alpha_i + \beta_i - \eta_i - \theta_i)$.

Equation (4) is the typical result of the partial information framework, with relative-price changes depending on real variables and the *unexpected* rate of inflation. To test the additional hypoth esis that *expected* inflation affects relative prices, e. g. , due to price adjustment costs, we add *EDP~* ad hoc to (4), to yield

$$Dp,t - DP^{t} = ge^{i} [-a; (DPt - EDP_{t}) + (3i (Dpmc - DP^{t}) + wti(Dy\sim - DP\sim) + Ee(DPt - DPwt> + \psi_i (Dy_t^f - DPW_t) + \xi_i EDP_t \qquad (5)$$

The variability of relative-price changes in the model is then obtained by inserting (5) in (1), which gives

$$Vp_{t} = B_{1}(DP_{t} - EDP_{t})2 + B2(Dp,,,L - DPt)2 + B_{3}(Dyd - DPL)2 + B_{4}(DP_{t} - DPW_{t})_{2} + BS(Dyt - DPW_{t})2 + B_{6}(DP_{t} - EDP_{t})(Dp_{,,,x} - DP_{1}) + B_{7}(DP_{t} - EDP_{t})(Dyd - DPt) + B_{8}(DP_{t} - EDP_{t})(DP_{1} - DPW_{t}) + B_{9}(DP_{t} - EDPt)(Dy\sim - DPW_{t}) + Blo(Dp\sim,\sim - DP\sim)(DLJi - DPc) + Bm(D1\sim,nr - DPt)(DPt - DPW_{t}) + Bla(Dp,,,t - DP^{t})(Dyr - DPW\sim) + Bla(Dye - DPt)(DPt - DPw_{t}) + B14(Dy\sim - DP\sim)(Dyr - DPW_{t}) + B1s(DPe - DPWt)(DyW\ DPW\sim) + BL6EDPi + B_{17} EDPt(DP_{t} - EDP_{t}) + B_{1}\sim EDP\sim(Dp_{ru} - DPL) + B_{19} EDP\sim(Dyd - DP_{1}) + B_{2o} EDP_{t}(DP_{t} - DPWt) + B_{21} EDP_{t}(Dyt - DPwt) \qquad (s)$$

where the parameters and their expected signs are

$$81 =\sim w_i \frac{gi}{2} > O, \quad B2 = \sim w_i \frac{R^2}{\sim i} > O, \quad B3 = \sim w;\sim s > O, \; gi$$

$$\sim w; \frac{E^2}{2\, gi} > O, \quad B_5 = \quad \frac{\cdot\cdot}{g_i^2} > 0, \quad B_6 = 2 \sum w_i \frac{-\alpha_i \beta_i}{g_i^2} < 0,$$

$$87\text{-}2\sim w \text{`-} \frac{a2N\sim i}{gi} < O \qquad 88 = 2\sim wt\text{-} \frac{a2E'}{gi} < O,$$

$$B_9 = 2 \sum w_i \frac{-\alpha_i \psi_i}{g_i^2} < 0, \quad B_{10} = 2 \sum w_i \frac{\beta_i \mu_i}{g_i^2} > 0,$$

$$811 = 2\; \text{L.I} \; \frac{Ri\, Ei}{\sim i} < O, \quad B1s = 2\sim w_i \frac{Ri\text{`}Yi}{2\, gi} > O,$$

$$813 = 2\sim w_i \frac{\sim\text{'}i\;\; i}{2\, gi} < \sim\sim \qquad 814 = 2\sim \frac{w4N\text{"}i\text{`}f\text{'}i}{gi} > O\text{'}$$

$$815 = 2 \sim wl \frac{Ei\text{`}Yi}{g_i} < O, \quad B_{1s} - \frac{\sim 1}{\text{U}} \; w_i \frac{\sim 2\; z}{\sim i} > O,$$

$$B1, = 2\sim w;\text{-} \frac{a2\sim\text{`}}{\sim i}\, c O, \quad B1s = 2\sim w_i \frac{RiSi}{2\, gi} \sim O$$

$$819 = 2\tilde{L} rw\sim l\sim iz i\sim\sim, \; gi \quad Bg\sim = 2\sim w, \frac{E}{-2i\; \sim i}\, C0 \quad \text{and}$$

$$B_{21} = 2 \sum w_i \frac{\psi_i \xi_i}{g_i^2} \gtreqless 0 .$$

The variability of relative-price changes depends on the variability of: unexpected and expected inflation, changes in raw material prices, changes in domestic and foreign real income and the deviation from the purchasing power parity. If the law of one price holds, we should expect $(DP_i - DPW_t)$ not to deviate systematically from zero, and hence we should not expect B_4, B_g, B_{11}, B_{13}, B_{1s} and B_{20} to be significantly different from zero.

It remains to specify the information set h on which EDP_i

depends. We assume that the information set consists of information on past rates of inflation. Specifically, we shall use two alternative assumptions for EDP_t, extrapolative expectations

$$EDP_t = DP_{t-1} + a_0(DP_{t-1} - DP_{t-2}) + a_1(DP_{t-2} - DP_{t-3})$$

and adaptive expectations

$$EDP_t = (1-b)DP_{t-1} + (1-b)bDP_{t-2} + (1-b)b^2 DP_{t-3}. \qquad (8)$$

Though the theoretical support for these "naive" schemes is weak, they have received some support in empirical studies using survey expectations [see Defris and Williams (1979) and Jacobs and Jones (1980)].

The model specified here differs from the models in Parks (1978) and Blejer and Leiderman (1982) in two respects. First, we have introduced raw material prices in the model. It is likely that changes in raw material prices, reflecting e. g. oil-price changes, have influenced price variability in the period we study, 1951-1979. In 1974 and 1979, the years of the two oil-price shocks, there were large increases in both inflation and relative-price variability. Secondly, since the model is applied to Swedish data, we have also included foreign demand for Swedish goods in the model. Though inflationary expectations are more restrictive than in the modified Lucas model of Cukierman and Wachtel (1979), the model here is more general in the sense that it incorporates raw materials, open economy characteristics and allows unequal supply responses across markets.

3. Data, Estimation and Empirical Results

I have used annual Swedish data for the period 1951-1979. It would have been preferable to use quarterly data. Almost all prices are changed within a year in an inflationary economy. So, the variability of prices across markets of sticky and flexible prices is less well represented by annual data. However, there is no consistent set of Swedish quarterly data for the variables in the model.

All the data come from national accounts statistics. Dp_{rt} is the implicit price index for raw materials and Dyd is the change in nominal GNP in Sweden. Price data for price variability, Vp_t, and inflation, DP_t, are individual prices from the consumer price index series and the CPI, respectively. The empirical results reported here are for the case where Vp_t has been measured by the unweighted variance, setting $w_{it} = 1/n_t$, where n is the number of commodities. The same measure was used by Vining and Elwertowsld (1976). Here the number of commodities varies over time, with a minimum of 212, and a maximum of 335.[3]

Dy_t has been measured as annual relative changes in GNP for 12 OECD-countries, those countries which are the most important trade partners for Sweden. Each country's GNP-change is weighted by its share of the 12 countries' total imports to Sweden. Dy_t can be written as

$$Dy_t = \sum_k \frac{M_{kt}}{\sum_k M_{kt}} Dy_{kt}, \qquad k = 1, \ldots, 12$$

where M_{kt} is the value of imports from country k at time t and Dy_{kt} is the change in GNP in country k at time t. These 12 countries accounted for approximately 70% of total Swedish imports in 1979.

DPW_t has been constructed in a similar way. Each country's consumer price index, DP_{kt}, has been weighted to give

$$DPW_t = \sum_k \frac{M_{kt}}{\sum_k M_{kt}} DPW_{kt}. \qquad k = 1, \ldots, 12$$

In the measurement of Dy_t and DPW_t, Dy_{kt} and DPW_{kt} has been adjusted with respect to changes in exchange rates. Hence, if changes in exchange rates equal the purchasing power parities, $(DP_t - DPW_t)$ equals zero.

The model can be tested in two alternative ways: through estimations of the Equations (5) for changes in relative commodity prices or through estimating Equation (6) for the variability of relative-price changes. The latter alternative is chosen here.[4] To estimate (6) a stochastic structure has to be imposed. A stochastic disturbance term u_{it} is added to (5), with $E(u_{it}) = 0$ and $E(u_{it})^2 =$

[3] In Assarsson (1984) two other measures of Vp_t were used, both being weighted variances. In one case a highly aggregated measure with only six commodity groups was used and in another case a measure with 44 constant-quality commodities was used. However, the estimations with these variance measures performed poorly.

[4] In Assarsson (1984) results are also given for the alternative tests with the equations based on (5). The results in general were consistent with the results reported here.

v^2, where v^2 is positive and finite. This stochastic structure can be rationalized on the grounds that shocks to the supply and the demand functions are permanent and hence that (5) follows a random walk. Now,

$$Vp_t = \sum w_{it}^2 (Dp_{it} - DP_t)^2 + \sum w_{it}^2 u_{it}^2 + 2 \sum w_{it}^2 (Dp_{it} - DP_t) u_{it} .$$

The last term in the above expression is nasty, considering the estimation of (6). However, it can be deleted in the estimation, without giving rise to bias in the estimated parameters, since the variables in the last term are random and hence do not systematically covary with the independent variables used in the estimation. With the last term in the above expression deleted, the error term in (6) is a sum of squared normally distributed random variables and hence is chi-square distributed. However, from the Central Limit Theorem, we know that the distribution of a sum of n independent, identically distributed random variables is asymptotically normal and, hence, as $n \to \infty$ the error term $\sum w_{it}^2 u_{it}^2$ approaches the shape of the normal density with positive and finite mean and variance. Since n here is relatively large, OLS is appropriate in estimating (6). But, since $E(\sum w_{it}^2 u_{it}^2) > 0$, an intercept, B_0, should be included in (6), where B_0 is expected to be positive.

These regressions are joint tests of the model and the assumed expectations formation. Adding an error term, the unexpected rate of inflation, to Equations (7) and (8), and replacing the left-hand sides of these equations with DP_t, we get the equations

$$DP_t = DP_{t-1} + a_0(DP_{t-1} - DP_{t-2}) + a_1(DP_{t-2} - DP_{t-3}) + v_t \qquad (9)$$

and

$$DP_t = (1 - b)DP_{t-1} + (1 - b)bDP_{t-2} + (1 - b)b^2DP_{t-3} + e_t . \qquad (10)$$

Equation (9) is estimated by OLS and in (10) we estimate b by maximum likelihood.[5]

In the regressions we have, if necessary, corrected for first-order autocorrelation following the rule in Engle (1974). If $\rho > 0.6$,

[5]In (9) the estimated coefficients were: $a_0 = -0.32$ and $a_1 = -0.47$, with standard errors 0.17 and 0.18, respectively. In (10) $b = 0.41$ with the standard error 0.14.

and is statistically significant, we accept the AR(1) error process and make the appropriate modifications. Otherwise, we do not reject the hypothesis of serially uncorrelated errors.

The main hypothesis to test is whether the expected rate of inflation significantly affects the variability of relative-price changes. In addition, it is interesting to test if the inclusion of raw materials and the open economy characteristics significantly improves the fit of the model. We test these hypotheses through the likelihood ratio test, with the risk of some small sample bias. In the likelihood ratio test the more restricted model is the null hypothesis. Excluding the variables implied by expected inflation and raw material prices implies *6* restrictions in each case, and excluding the variables implied by the open economy characteristics implies 11 restrictions. Since we use this test we are not primarily interested in single regression coefficients. Also, since multicollinearity among the independent variables in general exists here, it is less of a problem in the tests, since the correlation between the omitted and the remaining variables is low.

The regression results with equation (6) are reported in Table 1. Here we only give the results for *EDP~* as given by extrapolative expectations. The empirical results with adaptive expectations were not substantially different. Only a few variables are significant at

TABLE *1.* *Results from Regression with Equation (6), where Vp~ is the Dependent Variable**

Independent Variables	Parameters
Constant	*0.00514*
	(0.830)
(DPt - EDPt)2	*2.692*
	(5.482)
(Dpm~ - DPt)2	*0.070*
	(0.211)
(Dyd - DPt)2	*-0.161*
	(-0.260)
(DPt - DPWt)2	*0.116*
	(*o.* 061)
(Dye - DPWt)2	*-0.365*
	(-1.843)
(DPt - EDPt)(Dp„~~ – DPt)	*-1.068*
	(-l.lss)

TABLE 1. *Results from Regression with Equation (6), where Vp t is the Dependent Variable (cont'd)*

Independent Variables	Parameters
(DPt - EDPt)(Dyd - DPI)	-3.072
	(-2. 234)
(DPl - EDPt)(DPt - DPWt)	-3.437
	(-1.511)
(DPl - EDP~)(Dy t - DPWt)	0.358
	(0.192)
(Dpmt – DPt)(Dyd t - DPt)	-1.388
	(-1.089>
(Dpm~ - DPt)(DPt - DPWt)	7.922
	(1.922)
(Dpme - DP~)(Dyt - DPWt)	-0.646
	(-o.6so)
(Dyd - DPt)(DP~ - DPw~)	1.690
	(0.761>
(Dyd t – DPt)(Dy~ - DPWt)	0.097
	(0.152)
(DPt - DPWt)(Dy t - DPWt)	1. 588
	(1.451)
EDP~	0.233
	(0.453)
EDPt(DPt - EDPt)	3.236
	(5.390)
EDPt(Dp,,~t - DPt)	2.146
	(5. 00l)
EDP~(Dyd - DPt)	-0.572
	(-o. 583)
EDPt(DPt - DPWt)	-2.136
	(-2.104)
EDPt(Dyi - DPWL)	0.781
	(1.933)

NOTES:
*The error process is AR(1) with p = 0.96. t-values are given in parentheses.
Log of likelihood function = 179.97
Mean of dependent variable = 0.00623
Standard error of the regression = 0.000929
R~ = 0.974

the 5% level. Some of the coefficients also appear with the wrong signs.

The results are difficult to interpret due to multicollinearity among the independent variables. When we dropped the cross-terms in the model, the log of the likelihood function fell drastically and the restricted model was strongly rejected by our data, contrary to the findings in Blejer and Leiderman (1982).

The estimated parameters in Table 1 are not so interesting in themselves. Some parameters appear with the wrong sign but these are insignificant. The hypothesis tests are presented in Table 2, showing that the null hypotheses are rejected. Hence, the hypotheses that expected inflation, raw material prices and the open economy characteristics do not influence the variability of relative-price changes is rejected at the 1% significance level. Ignoring the

TABLE 2. *Likelihood Ratio Tests. (The Critical Values of the Chi-Square Distribution Have Been Selected for the 1% Significance Level.)*

Likelihood Values:

Model:	
(6)	179.97
(6) excl. expected inflation	152.53
(6) excl. raw material prices	147.34
(6) excl. the foreign variables	153.62

(i) Test of expected inflation

$2(179.97 - 152.53) = 54.88$

$\chi^2(6) = 16.81$

(ii) Test of raw material prices

$2(179.97 - 147.34) = 65.26$

$\chi^2(6) = 16.81$

(iii) Test of the foreign variables

$2(179.97 - 153.62) = 52.70$

$\chi^2(11) = 24.73$

possible small sample bias, the model specification in (6) is thus supported by our data.

4. Conclusions

Recent studies of the behavior of the variability of relative-price changes and of the relationship between inflation and relative-price variability show a systematic relationship between these variables. Fischer (1981a, 1982) also found that the expected rate of inflation influenced price variability in USA and West Germany, but in Blejer (1979, 1981) and Blejer and Leiderman (1982), for Mexico and Argentina, the major influence is from unexpected inflation.

The results found here, based on the assumption that inflation is the causative factor, are that expected inflation plays a major role for relative-price change variability. We have used two alternative assumptions for the formation of expectations, extrapolative and adaptive expectations, but there are no major differences between the two cases. The results are in line with those in Fischer (1982), who used the actually observed expectations in the Michigan survey for USA. Therefore, this result seems to be stable under different assumptions on expectations formation.

In addition, it is shown that raw material prices as well as the foreign demand variables are important determinants of relative-price variability. It seems likely that supply shocks are important for relative-price variability and that the two oil price shocks of the 70s were important in the inflationary process.

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~In Assarsson (1984) some experiments with vector autoregressions were done. In decompositions of the moving average representation into a forecast and the accumulated effects of past and current shocks in the system, it was shown that the two oil price shocks had large effects on both Vp, and DP~.

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