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Abstract This paper reexamines the proxy hypothesis of Fama (American Economic Review, 1981, 71, 545-565) as the main explanation for the negative correlation between stock returns and inflation. We look at quarterly data on industrial-production growth, monetary-base growth, CPI inflation, three-month Treasury-bill rates, and returns on the equally-weighted NYSE portfolio, for the 1954–1976 and 1977–1990 periods. Using time-series techniques, we find that production growth induces only a weak negative correlation between inflation and stock returns, and explains less of the covariance between the two series than inflation and interest-rate innovations.

Keywords: vector autoregression, vector moving average, covariance decomposition

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1 Introduction

The existence of a negative significant correlation between inflation and returns on common stocks in the postwar U.S. data is a well-established empirical fact, beginning with the three studies by Jaffe and Mandelker (1976), Bodie (1976), and Nelson (1976). Such empirical fact is further documented by Fama and Schwert (1977), and in his well-known 1981 article Fama outlines the "proxy hypothesis" as its main explanation. The explanation is based on two stylized facts. First, high inflation rates anticipate low growth rates of (real) aggregate economic activity: as economic-activity growth is expected to slow down, the growth rate of the demand for real cash balances is also expected to decrease, leading to an increase in future-expected and current inflation. Second, high (real) stock returns anticipate high growth rates of aggregate economic activity. As a result, inflation and stock returns are driven in opposite directions by anticipated business fluctuations, and correlate negatively. Geske and Roll (1983) elaborate on Fama's explanation, arguing that the countercyclical fiscal policy followed by the U.S. during the post-war period induced a procyclical behavior of money supply, due to deficit monetization. This behavior, in turn, reinforced the mechanisms of the proxy hypothesis, because of higher inflation rates during recessions.

The present paper uses vector autoregressions (VARs) and the implied vector moving averages (VMAs) to test the proxy hypothesis in a flexible and informative way. We elaborate on the variance-decomposition exercises of Sims (1980a,b) to perform a *covariance* analysis which provides a measure of the strength of the correlation between inflation and stock returns, according to the origin of the perturbations affecting the system. Also, we break down the total covariance between the two series into components due to innovations in different variables.

We find that inflation and stock returns exhibit the strongest correlation when the inflation rate itself is the variable shocked. Innovations in the inflation rate also account for most of the negative covariance between the two series. We then extend the analysis to the nominal rate of interest. Inflation and stock returns correlate strongly (and negatively) in response to interest-rate shocks, and interest-rate innovations account for a significant portion of the covariance between the two series. This effect is especially strong for the 1954–1976 period.

The paper is organized as follows: Section 2 lays out the techniques used in the covariance-decomposition exercises, while Section 3 illustrates the empirical results. Section 4 concludes and summarizes the main results of the paper.

2 Covariance decompositions

The four variables involved in the analysis are industrial-production growth (q_t), CPI inflation (p_t), monetary-base growth (m_t), three-month Treasury-bill rate (i_t), and real returns on the value-weighted NYSE portfolio (r_t). The first three series are measured in annual percentage points, while real stock returns are in monthly percentage points; the periodicity of the data is quarterly, and all series are seasonally unadjusted. Further details on variable definitions and data sources are available in the Appendix.

The quarterly periodicity is chosen because it represents a good compromise between the number of observations available, and the "smoothness" of the data; also, we prefer to work with non-overlapping, seasonally-unadjusted data to avoid the problems arising from overlapping observations, and the possible loss of relevant information due to seasonal adjustment. As to the choice of the four series, we are motivated by two orders of considerations: First, it makes our results directly comparable with those obtained in Fama (1981), and by other studies such as James, Koreisha, and Partch (1985), and Lee (1992). Second, Fama (1990) argues that industrial production explains as much or more stock-return variation as other real-activity variables; and Fama (1980) finds that the monetary base has always more power in explaining inflation than other monetary measures.

Let $\mathbf{Y}_t \equiv [q_t, p_t, m_t, r_t]'$. We assume $\mathbf{Y}_t$ to have the representation

$$\mathbf{Y}_t - A_1\mathbf{Y}_{t-1} - A_2\mathbf{Y}_{t-2} - \ldots - A_4\mathbf{Y}_{t-4} = \mathbf{A}(L)\mathbf{Y}_t = \mathbf{S}_t + \mathbf{v}_t, \quad E(\mathbf{v}_t\mathbf{v}_t') = \mathbf{\Sigma}.$$

The matrix polynomial in the lag operator $\mathbf{A}(L)$ satisfies $\mathbf{A}(0) = \mathbf{I}$; $\mathbf{S}_t = \mathbf{S}_{t+4}$ is a vector of time-varying intercepts describing seasonal effects, while $\mathbf{v}_t \equiv [v_{qt}, v_{mt}, v_{pt}, v_{rt}]'$ is a vector of serially uncorrelated random shocks with covariance matrix $\mathbf{\Sigma}$.

Assuming stationarity, the matrix polynomial $\mathbf{A}(L)$ can be inverted to obtain the infinite-moving-average representation

$$\mathbf{Y}_t = \mathbf{A}(L)^{-1}\mathbf{S}_t + \mathbf{A}(L)^{-1}\mathbf{v}_t = \sum_{n=0}^{\infty}\mathbf{C}_n\mathbf{S}_{t-n} + \sum_{n=0}^{\infty}\mathbf{C}_n\mathbf{v}_{t-n}, \tag{1}$$

where $C_0 = I$, and

$$\begin{aligned} C_n &= C_{n-1}A_1 + C_{n-2}A_2 + \ldots + C_0A_n, \quad n < P \\ C_n &= C_{n-1}A_1 + C_{n-2}A_2 + \ldots + C_{n-P}A_P, \quad n \geq P. \end{aligned}$$

In general $\mathbf{\Sigma}$ is not diagonal, and the elements of $\mathbf{v}_t$ cannot be attributed to a specific series; a shock to one series is likely to be met by shocks to other series. Identification can still be achieved imposing a minimum of economic structure on the VAR.

In order to make our results fully comparable with those of Fama (1981) the following set of identifying assumptions replicates the causality structure of his models. Innovations in production and money growth are predetermined relative to innovations in the other two series: this is consistent with a view of the economy where production and money growth are the forcing processes, while inflation and stock returns are determined endogenously. We also let production-growth innovations affect money-growth innovations, but not viceversa, to reflect the delay in the effects of monetary policy on the real economy, and the possibility of a reaction of monetary policy to business fluctuations. Inflation innovations are affected by production- and money-growth innovations; and within the quarter stock returns are affected by the other three variables, but do not affect any of them. In other words, we assume the following Markov causal chain for the vector $\mathbf{v}_t$:

$$q_t \Longrightarrow m_t \Longrightarrow p_t \Longrightarrow r_t.$$

In order to implement our identifying assumptions, we compute the Choleski factor $\mathbf{G}$ of the matrix $\mathbf{\Sigma}$: a *lower triangular* matrix, such that

$$\mathbf{G}\mathbf{G}' = \mathbf{\Sigma}.$$

Premultiplying $\mathbf{v}_t$ by the lower triangular matrix $\mathbf{G}^{-1}$, we obtain the vector $\mathbf{w}_t$ of unit-variance orthogonal random shocks:

$$\mathbf{w}_t = \mathbf{G}^{-1}\mathbf{v}_t, \qquad E\left(\mathbf{w}_t\mathbf{w}_t'\right) = \mathbf{I}.$$

Therefore the VMA representation (1) can be rewritten in terms of the orthogonal innovation vector $\mathbf{w}_t$:

$$\mathbf{Y}_t = \sum_{n=0}^{\infty} \mathbf{C}_n\mathbf{S}_{t-n} + \sum_{n=0}^{\infty} \mathbf{C}_n\mathbf{G}'(\mathbf{G}')^{-1}\mathbf{v}_{t-n} = \sum_{n=0}^{\infty} \mathbf{C}_n\mathbf{S}_{t-n} + \sum_{n=0}^{\infty} \mathbf{H}_n\mathbf{w}_{t-n}.$$

Concentrating on the *indeterministic* component of the series, the inflation rate p_t and the stock return r_t can be written as

$$p_t = \sum_{n=0}^{\infty} h_{pqn}w_{qt-n} + \sum_{n=0}^{\infty} h_{pmn}w_{mt-n} + \sum_{n=0}^{\infty} h_{ppn}w_{pt-n} + \sum_{n=0}^{\infty} h_{prn}w_{rt-n} \quad (2)$$

$$r_t = \sum_{n=0}^{\infty} h_{rqn}w_{qt-n} + \sum_{n=0}^{\infty} h_{rmn}w_{mt-n} + \sum_{n=0}^{\infty} h_{rpn}w_{pt-n} + \sum_{n=0}^{\infty} h_{rrn}w_{rt-n}, \quad (3)$$

where h_{pqn} is the element of the matrix $\mathbf{H}_n$ in the row corresponding to the inflation rate, and the column corresponding to production growth; the quantity h_{pqn} denotes the effect on the inflation rate of a unit change in industrial production, after n periods.

We develop upon the analysis above, and suggest an application of the moving average representations (2) and (3) which allows to decompose the *covariance* between inflation and stock returns (or between any other two series) as follows:

$$\begin{aligned}\sigma_{pr} &= \left(\sum_{n=0}^{\infty} h_{pqn}h_{rqn}\right) + \left(\sum_{n=0}^{\infty} h_{pmn}h_{rmn}\right) + \left(\sum_{n=0}^{\infty} h_{ppn}h_{rpn}\right) + \left(\sum_{n=0}^{\infty} h_{prn}h_{rrn}\right) \\ &\equiv \sigma_{pr|q} + \sigma_{pr|m} + \sigma_{pr|p} + \sigma_{pr|r}.\end{aligned}$$

The nature of the decomposition is easily understood. For example, the term $\sigma_{pr|q} \equiv \sum_{n=0}^{\infty} h_{pqn}h_{rqn}$ represents the covariance between p_t and r_t *conditional* on all innovations, but the ones affecting production growth, being zero. This quantity describes the following thought experiment: Assume the system to be initially at the steady state, and then allow innovations to affect only one of the variables, in this case industrial production; we then look at the moments of the series generated by the dynamic system. In this case, the conditional covariance is high (in absolute value) if industrial-production innovations: i) explain a high portion of the variance of inflation and stock returns, and ii) induce fluctuations in opposite directions in the two series.

The covariance decomposition illustrated above can be used to perform two types of exercise. First, we can calculate the intensity of the *correlation* between inflation and stock returns according to the origin of the innovation:

$$\rho_{pr|k} = \frac{\sigma_{pr|k}}{\sigma_{p|k}\sigma_{r|k}}, \quad k = q, m, p, r,$$

where $\sigma_{p|k}$ and $\sigma_{r|k}$ denote the variances of p_t and r_t *conditional* on all innovations, but those of the kth variable, being zero.[1] Second, we can evaluate the contribution of the different innovations to the *covariance* between inflation and stock returns; we have

$$\sigma_{pr} = \sigma_{pr|q} + \sigma_{pr|m} + \sigma_{pr|p} + \sigma_{pr|r}.$$ [2]

3 Empirical results

All tests have been performed separately for the sample period studied in Fama (1981), 1954:1–1976:4, and for the later period 1977:1–1990:4.

In Table 1, we report the results of the covariance-decomposition exercises for inflation and stock returns.

Table 1 about here

We find that for both periods the contemporaneous correlation between inflation and stock returns is always negative, irrespective of the origin of the innovation; and the correlation is strongest when the system is hit by inflation shocks. Moreover, innovations in inflation explain 64% and 45% of the covariance between inflation and stock returns, for the 54–76 and 77–90 periods, respectively.

We also extend our analysis to include the rate of interest. As a measure of the interest rate we use the three-month Treasury-bill rate, sampled at the end of the third month of each quarter. As to identification, we assume the interest rate to be affected by innovations in production and money growth, and in the inflation rate; whereas interest-rate innovations affect stock returns. The resulting Markov causal chain has the form

$$q_t \Longrightarrow m_t \Longrightarrow p_t \Longrightarrow i_t \Longrightarrow r_t.$$

The covariance-decomposition exercises are summarized in Table 2.

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[1] Note that we could decompose the unconditional inflation "beta," (σ_{rp}/σ_p^2) of the NYSE value-weighted portfolio in a similar way.

[2] Note that this decomposition is meaningful only if the sign of all conditional covariances is the same, which is the case for inflation and stock returns.

Table 2 about here

While inflation innovations still induce the strongest negative correlation between inflation and stock returns, and explain most of the covariance between the two series, interest-rate innovations now play a significant role. During the 54–76 period, interest-rate innovations produce a negative correlation coefficient of $-.73$ (second, in absolute value, only to that produced by inflation innovations), and account for almost 20% of the covariance. During the 77–90 period, interest-rate innovations still induce the second strongest negative correlation, although the percentage of covariance that they explain falls to 7.66%.

4 Conclusions

In summary, this paper makes the following contributions: First, it shows how vector moving averages can be used to study the correlation and the covariance between two series. This application complements the variance-decomposition exercises introduced by Sims (1980a,b). Second, it finds that inflation itself is responsible for most of the dynamic interaction with stock returns. Third, it finds that the rate of interest accounts for a substantial share of the negative correlation between stock returns and inflation.

Appendix: Data description

Production growth, q_t, is the quarterly change in the log of the monthly index of industrial production, seasonally unadjusted (Board of Governors of the Federal Reserve System). Inflation, p_t, is the quarterly change in the log of the monthly consumer price index, urban consumers, seasonally unadjusted (U.S. Department of Labor, Bureau of Labor Statistics). Money growth, m_t, is the quarterly change in the log of the monthly monetary base, seasonally unadjusted (Federal Reserve Bank of St. Louis). The interest rate, i_t, is the yield on the Treasury bill with maturity closest to 90 days at the end of the quarter (Center for Research in Security Prices of the University of Chicago, CRSP). Nominal stock returns are the rates of returns on the value-weighted NYSE index, continuously compounded (CRSP). Real stock returns, r_t, are the difference between nominal stock returns and the realized inflation rate for the corresponding quarter.

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Table 1. Covariance analysis; VAR: q_t, m_t, p_t, r_t

We report the *conditional* correlation coefficients between inflation and stock returns, and the relative contribution of different innovations to the covariance between inflation and stock returns, after 16 lags.

1954:1–1976:4

k:	q	m	p	r
$\rho_{pr\|k}$	-.43	-.66	-.82	-.26
$100\sigma_{pr\|k}/\sigma_{pr}$	7.24	18.89	64.25	9.62

1977:1–1990:4

k:	q	m	p	r
$\rho_{pr\|k}$	-.43	-.39	-.57	-.27
$100\sigma_{pr\|k}/\sigma_{pr}$	16.93	14.70	45.98	22.38

Table 2. Covariance analysis; VAR: q_t, m_t, p_t, i_t, r_t

We report the *conditional* correlation coefficients between inflation and stock returns, and the relative contribution of different innovations to the covariance between inflation and stock returns, after 16 lags.

1954:1–1976:4

k:	q	m	p	i	r
$\rho_{pr\|k}$	-.45	-.59	-.85	-.73	-.27
$100\sigma_{pr\|k}/\sigma_{pr}$	8.92	17.28	42.85	19.51	11.44

1977:1–1990:4

k:	q	m	p	i	r
$\rho_{pr\|k}$	-.44	-.37	-.61	-.49	-.28
$100\sigma_{pr\|k}/\sigma_{pr}$	23.30	15.17	31.96	7.66	21.91