The stock return-inflation puzzle and the asymmetric causality in stock returns, inflation and real activity

Jeong-Ryeol Kim

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Deutsche Bundesbank, Wilhelm-Epstein-Strasse 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 95 66-1
Telex within Germany 4 1 227, telex from abroad 4 14 431, fax +49 69 5 60 10 71

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Abstract

In this paper, we use a modified concept of Granger-(non)causality in reconsidering the negative correlation between stock returns and inflation known in the literature as stock return-inflation puzzle. Based on the quarterly data for Germany including stock returns, inflation rates and growth rates of gross domestic production, it turns out that the proxy causality between stock returns and inflation may be regarded as an asymmetric one, and the indicative role of stock returns may be also asymmetrically Granger-causal to the growth rates of gross domestic production.

Zusammenfassung

In der vorliegenden Arbeit soll das konventionelle Konzept der Granger-Kausalität modifiziert werden, um die negative Korrelation zwischen Aktienrenditen und Inflationsrate zu untersuchen, das in der Literatur als Rätsel der Aktienrendite-Inflation-Relation (bzw. Proxy-Hypothese) bekannt ist. Es zeigt sich auf der Grundlage deutscher Quartalsdaten für Aktienrendite, Inflationsrate und Wachstumsrate des Inlandsprodukts, dass die Proxy-Kausalität zwischen Aktienrenditen und Inflationsrate als eine asymmetrische Beziehung anzusehen ist. Darüber hinaus ist die führende Rolle der Aktienrendite für die Wachstumsrate der Inlandsprodukts ebenfalls als eine asymmetrische Beziehung zu betrachten.

JEL classification: C12, E44

Keywords: Proxy hypothesis; Granger-causality; asymmetry; threshold; nonlinearity.

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E-Mail: jeong-ryeol.kim@bundesbank.de, Tel.: +49 69 9566 4576, Fax: +49 69 9566 2982.

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1 Introduction

The basic Fisher hypothesis states that the expected nominal rate of return on asset is equal to expected inflation plus the real rate of return, where the ex ante real rate of return is independent of expected inflation. There is, however, little empirical evidence which supports a positive relation between ex ante nominal returns and expected inflation. In contrast to the Fisher hypothesis, many empirical studies has shown a significant negative correlation between stock returns and inflation known in the financial economic literature as a stock return-inflation puzzle. There have been many empirical studies in the financial literature to explain this anomaly. Fama (1981) explains this phenomena as a proxying for positive relations between stock returns and real variables, which is termed proxy hypothesis. Geske and Roll (1983) argue that the spurious causality between stock returns and inflation results from a combination of a reversed adaptive inflation expectations model and a reversed money growth/stock returns model. In line with the findings of Geske and Roll (1983), James et al. (1985) also perceive a reversed causality in the context of vector autoregressive moving average analysis. Kaul (1987) finds evidence indicating that the negative stock return–inflation relations are caused by money demand and counter-cyclical money supply effects. Using a multivariate VAR approach, Lee (1992) strengthens the empirical evidence of Fama and shows that stock returns explain real activity but not inflation, while interest rates explain inflation and inflation does not explain real activity. Balduzzi (1995) examines the proxy hypothesis based on a variance decomposition analysis and finds that production growth induces only a weak negative correlation between inflation and stock returns. He also finds a stronger covariance between inflation and interest rates than between stock returns and inflation. More recently, Gallagher and Taylor (2002) develop a theoretical model for testing the proxy hypothesis and conclude that real stock returns are strongly significantly negatively correlated with inflation purely due to supply innovation exactly as the proxy hypothesis states.

This paper considers the causal relations between stock returns and inflation as well as those between stock returns and the growth rate of gross domestic production. The main econometric method for analyzing causalities in the context of the proxy hypothesis is a refined version of Granger-causality, namely symmetric and asymmetric Granger-causality.

The rest of the paper is organized as follows: in Section 2 we provide definitions and econometric testing procedures for asymmetric Granger-causality. Section 3 provides an empirical analysis and its findings. Section 4 summarizes the paper and contains some concluding remarks.

2 Testing asymmetry

Non-linear regression analysis: Linear regressions as surveyed in the previous section are usually used for the analysis of proxy hypothesis. A non-linear regression is also a useful complementary for the analysis of proxy causality as follows:

$$y_t = \nu + ax_t + b\mathrm{I}_{\{\Phi\}}(\Delta x_t), \tag{1}$$

where $\mathrm{I}_{\{\Phi\}}(\Delta x_t)$ is defined as

$$\mathrm{I}_{\{\Phi\}}(\Delta x_t) := \begin{cases} 1, & \text{if } \Delta x_t \in \Phi \\ 0, & \text{otherwise.} \end{cases}$$

Above, Φ is a set of real numbers which determines what kind of asymmetry is assumed under null hypothesis and Δ is the first difference operator. Typically, two features of asymmetry are considered in this paper. The first one is

$$\Phi = \{\Delta x_t | \Delta x_t \in (-\infty, 0]\}. \tag{2}$$

This type of asymmetry[1] will be assumed under null hypothesis if the asymmetry depends on the sign of the exogenous variable Δx. The other is

$$\Phi = \{\Delta x_t || \Delta x_t| \in [\theta, \infty)\}. \tag{3}$$

Clearly, this type of asymmetry will be assumed under null hypothesis if the asymmetry depends on the absolute magnitude of the exogenous variable Δx from zero.[2] This case may be regarded as a threshold regression with a threshold parameter θ.

Asymmetric Granger-causality: Test for Granger-(non)causality (Granger, 1969) is usually performed in an autoregressive model with exogenous variables (ARX). This idea can be extended in a non-linear ARX model in order to test for asymmetric Granger-(non)causality. To provide a formal definition of a symmetric and asymmetric Granger-causality, three types of mean squared error (MSE) are defined as follows:

$$\begin{aligned} MSE_1 &:= MSE\{\hat{\mathrm{E}}[y_{t+s}|y_t, y_{t-1}, \ldots]\} \\ MSE_2 &:= MSE\{\hat{\mathrm{E}}[y_{t+s}|y_t, y_{t-1}, \ldots, x_t, x_{t-1}, \ldots]\} \\ MSE_3 &:= MSE\{\hat{\mathrm{E}}[y_{t+s}|y_t, y_{t-1}, \ldots, x_t, x_{t-1}, \ldots, \mathrm{I}_{\{\Phi\}}(\Delta x_t), \mathrm{I}_{\{\Phi\}}(\Delta x_{t-1}), \ldots]\}, \end{aligned}$$

where $MSE\{\cdot\}$ is defined to be the mean-squared error operator.

[1] Depending on the characteristic of time series, one can equivalently write $\Phi = \{\Delta x_t | \Delta x_t \in [0, \infty)\}$.

[2] For this case Δx will be typically a demeaned variable by a log-difference operator such as growth rates.

Definition 1 *According to Granger (1969), x is Granger-causal to y if for all $s > 0$ the MSE of a forecast of y_{t+s} that uses both $y_t, y_{t-1}, \ldots$ and $x_t, x_{t-1}, \ldots$ is smaller than the MSE of a forecast of y_{t+s} based only on $y_t, y_{t-1}, \ldots$ so that*[3]

$$MSE_1 > MSE_2. \tag{4}$$

Definition 2 *x is symmetric Granger-causal to y if for all $s > 0$ the MSE of a forecast of y_{t+s} that uses both $y_t, y_{t-1}, \ldots$ and $x_t, x_{t-1}, \ldots$ is smaller than the mean squared error (MSE) of a forecast of y_{t+s} based only on $y_t, y_{t-1}, \ldots$ and the former is the same as the MSE of a forecast of y_{t+s} based on $y_t, y_{t-1}, \ldots$ and $x_t, x_{t-1}, \ldots$ as well as $\mathrm{I}_{\{\Phi\}}(\Delta x_t), \mathrm{I}_{\{\Phi\}}(\Delta x_{t-1}), \ldots$ so that*

$$MSE_1 > MSE_2 = MSE_3. \tag{5}$$

Definition 3 *x is asymmetric Granger-causal to y if for all $s > 0$ the MSE of a forecast of y_{t+s} that uses both $y_t, y_{t-1}, \ldots$ and $x_t, x_{t-1}, \ldots$ is smaller than the mean squared error (MSE) of a forecast of y_{t+s} based only on $y_t, y_{t-1}, \ldots$ and the former is larger than the MSE of a forecast of y_{t+s} based on $y_t, y_{t-1}, \ldots$ and $x_t, x_{t-1}, \ldots$ as well as $\mathrm{I}_{\{\Phi\}}(\Delta x_t), \mathrm{I}_{\{\Phi\}}(\Delta x_{t-1}), \ldots$ so that*

$$MSE_1 > MSE_2 > MSE_3. \tag{6}$$

To implement this test for Granger-(non)causality, one can specify an AR model with lag length p under the null hypothesis

$$y_t = \nu + \sum_{i=1}^{p} \alpha_i y_{t-i} + u_{0t} \tag{7}$$

and an ARX model under the alternative hypothesis of Granger-causality

$$y_t = \nu + \sum_{i=1}^{p} \alpha_i y_{t-i} + \sum_{i=1}^{p} \beta_i x_{t-i} + u_{1t}. \tag{8}$$

This ARX model can also be used under null hypothesis of non-asymmetric Granger-causality. Under alternative hypotheses one can specify the same ARX with terms capturing asymmetric dynamics such that

$$y_t = \nu + \sum_{i=1}^{p} \alpha_i y_{t-i} + \sum_{i=1}^{p} \beta_i x_{t-i} + \sum_{i=1}^{p} \gamma_i \mathrm{I}_{\{\Phi\}}(\Delta x_{t-i}) + u_{2t}. \tag{9}$$

Under the null hypothesis of Granger-noncausality, namely $H_0 : \beta_1 = \beta_2 = \cdots = \beta_p = 0$, the likelihood ratio statistic is usually based on ordinary least squares

$$[(T - 2p - 1)(RSS_0 - RSS_1)]/[p \times RSS_1] \tag{10}$$

[3] The original idea is defined as *non*causaliy. But for a better understanding of asymmetric causality we use Granger-causality.

is $F(p, T-2p-1)$-distributed, where the restricted and unrestricted sum of squared residuals is calculated as $RSS_0 = \sum_{t=1}^{T} \hat{u}_{0t}^2$ and $RSS_1 = \sum_{t=1}^{T} \hat{u}_{1t}^2$. Consequently, under null hypothesis of symmetric Granger-causality (under alternative hypothesis of asymmetric Granger-causality), namely $H_0 : \gamma_1 = \gamma_2 = \cdots = \gamma_p = 0$, the likelihood ratio statistic

$$[(T - 3p - 1)(RSS_1 - RSS_2)]/[p \times RSS_2] \tag{11}$$

is $F(p, T-3p-1)$-distributed, where RSS_1 is given above and $RSS_2 = \sum_{t=1}^{T} \hat{u}_{2t}^2$.

3 Empirical application

The three variables involved in the empirical analysis are returns on the value-weighted German stock index (DAX) portfolio (r_t), inflation (π_t) based on the gross domestic product (DGP) deflator[4] and growth rates of GDP (q_t). All the series are measured in annual percentage points[5] and the periodicity of the data is quarterly. They cover the period from 1970 I to 1999 IV (120 observations) and are taken from the database of the Deutsche Bundesbank.

With respect to the proxy hypothesis and in the context of a bivariate analysis, two groups of variables are of interest. To determine exogenous variables in the regressions and ARX models in each group, we take the usual causal chains: $\pi_t \to r_t$ and $\mathrm{E}[q_{t+s}] \to r_t$, where in our empirical analysis we will use q_{t+s} as a measure for the unobservable variable $\mathrm{E}[q_{t+s}]$.[6] Each of the groups can serve as testing for the following empirical issues:

– stock return-inflation (r_t, π_t): the proxy hypothesis
– stock return-expected growth rates of GDP $(r_t, \mathrm{E}[q_{t+s}])$: the indicative role of stock prices to real activity

Non-linear regression analysis: The estimation results of equation (1) combined with an asymmetric term (2) and (3) are summarized in Tables 1 and 2, with the regression of stock return-inflation in Table 1 and the regression of stock return-growth rates of GDP in Table 2. The estimate for θ is chosen by maximizing the t-value for the coefficient $\hat{b}_2$. For searching for the value of θ, at which the t-value of $\hat{b}_2$ is maximum, we use a simple grid method, i.e. regressions are estimated by given $\theta \in [\theta_{min}, \theta_{max}]$ with a step of $(\theta_{max} - \theta_{min})/\delta$, where δ can be determined

[4]Inflation based on the consumer price index instead of the DGP deflator gives approximately the same results.

[5]GDP deflator and GDP are seasonally unadjusted data.

[6]Alternatively, one can measure the expected GDP using the Kalman-filter method as performed by Lee (1992) and Gjerde and Sættem (1999) for measuring expected inflation.

arbitrarily.[7] In our empirical analysis, we set $\theta_{min} = 0.001$ and $\theta_{max} = 0.02$, i.e. $\delta = 20$, because $min\{|\Delta\pi_t|\} = 0.0001$ and $max\{|\Delta\pi_t|\} = 0.0229$. The number of $|\Delta\pi_t| \in [min\{|\Delta\pi_t|\}, \theta_{min})$ and $|\Delta\pi_t| \in (\theta_{max}, max\{|\Delta\pi_t|\}]$ is 15 and 2, respectively.

Table 1. Estimates of coefficients for return-inflation regression

Regression	$r_t = \nu_0 + a_0\pi_t$		$r_t = \nu_1 + a_1\pi_t + b_1 \mathrm{I}_{[0,\infty)}(\Delta\pi_t)$			$r_t = \nu_2 + a_2\pi_t + b_2 \mathrm{I}_{[\theta,\infty)}(\lvert\Delta\pi_t\rvert)$			
Coefficients	$\hat{\nu}_0$	$\hat{a}_0$	$\hat{\nu}_1$	$\hat{a}_1$	$\hat{b}_1$	$\hat{\nu}_2$	$\hat{a}_2$	$\hat{b}_2$	$\hat{\theta}$
Estimates	0.17	-2.53	0.17	-2.55	0.01	0.17	-2.08	-0.10	0.01
t-value[a]	(6.07)	(3.44)	(5.62)	(3.30)	(0.37)	(5.99)	(2.73)	(2.34)	

[a] t-values are given in absolute value.

The proxy hypothesis of Fama (1981) also confirms German data considered, i.e. the correlation between stock return and inflation is negative (-2.53) and highly significant. The estimated regression in (1) with an asymmetric term given in (2) shows that the sign of the changes of inflation has no effect on the stock returns. But the same regression with an asymmetric term given in (3) clearly shows that the big (positive and negative) changes do matter for the stock returns. A big change in inflation induces a significant negative reaction (-0.10) in the changes of stock returns, where the threshold parameter is 0.01, say 1%.[8]

In order to see whether the stock market is determined by means of expectations about the future development of real activity, we specify a regression with a lead from 0 to 4 as $r_t = \nu + aq_{t+j}$, $j = 0, 1, 2, 3, 4$ and add the asymmetric terms in (2) and (3) to each regression.

The results of stock return-real activity regression in Table 2 show that the stock returns play an indicative role concerning the development in future real activity, namely the first three lead terms ($j = 0, 1, 2$) are significant. This phenomenon was also recently observed by Estrella and Mishkin (1998) who find in US data that stock prices are useful with one to three-quarter horizons for prediction of real activity. The regressions with an asymmetric term in (1) show that, in contrast to the return-inflation regression, the sign of changes of the growth rates of GDP has an influence on the stock returns, while the magnitude of the changes of GDP is not very significant.

Asymmetric Granger-causality: In order to test for asymmetric Granger-causality we specify the auxiliary regressions given in (7), (8) and (9), where, based upon the results in Table 2 and the empirical evidence of Estrella and Mishkin (1998), p is assumed to be 3. For all θ_i, $i = 1, 2, 3$, we set $\theta_{min} = 0.001$ and $\theta_{max} = 0.01$ with

[7] In order to avoid singularity, $\theta_{min} > min\{|\Delta x_t|\}$ and $\theta_{max} < max\{|\Delta x_t|\}$.

[8] The number of $\Delta\pi_t > 0.01$ and $\Delta\pi_t < -0.01$ is 6 and 8, respectively.

Table 2. Estimates for coefficients of regression for stock return and real activity[ab]

Regression Coefficients	(r_t, q_t)	(r_t, q_{t+1})	(r_t, q_{t+2})	(r_t, q_{t+3})	(r_t, q_{t+4})
$\hat{\nu}_0$	0.05(2.56)	0.05(2.38)	0.06(3.21)	0.08(4.38)	0.09(4.37)
$\hat{a}_0$	1.61(2.69)	1.75(2.89)	1.00(1.61)	-0.03(0.04)	-0.03(0.05)
$\hat{\nu}_1$	0.01(0.18)	-0.02(0.71)	-0.00(0.10)	0.04(1.41)	0.08(2.71)
$\hat{a}_1$	2.35(3.53)	2.78(4.22)	2.08(3.03)	0.65(0.91)	-0.04(0.06)
$\hat{b}_1$	0.06(2.04)	0.09(3.13)	0.09(3.03)	0.07(2.13)	0.01(0.39)
$\hat{\nu}_2$	0.01(0.37)	0.01(0.31)	0.02(0.47)	0.10(1.81)	0.01(0.30)
$\hat{a}_2$	1.63(2.68)	1.71(2.81)	0.99(1.56)	1.73(2.83)	-0.30(0.46)
$\hat{b}_2$	0.05(1.28)	0.05(1.23)	0.06(1.62)	-0.05(0.96)	0.10(2.23)
$\hat{\theta}$	0.005	0.005	0.005	0.005	0.003

[a] t-values (in absolute value) are reported in parentheses.

[b] Coefficients come from the following three regressions: $r_t = \nu_0 + a_0 q_{t+j}$; $r_t = \nu_1 + a_1 q_{t+j} + b_1 \mathrm{I}_{(-\infty,0]}(\Delta q_{t+j})$ and $r_t = \nu_2 + a_2 q_{t+j} + b_2 \mathrm{I}_{[\theta,\infty)}(|\Delta q_{t+j}|)$, $j = 0, 1, 2, 3, 4$.

step length of 0.001 and estimate θ_1, θ_2 and θ_3 simultaneously at which the SSR_{22} has its minimum from the 100^3 combinations of $\hat{\theta}_1$, $\hat{\theta}_2$ and $\hat{\theta}_3$.[9] Table 3 shows the results of the test for symmetric and asymmetric Granger-causality.

Table 3. Test for asymmetric Granger-causality[ab]

Statistics	SSR_0	SSR_1	SSR_{21}	SSR_{22}	TS_1	TS_{21}	TS_{22}
Estimates	0.0509	0.0454	0.0425	0.0403	4.4119	2.3948	4.9211
p-value					(0.0057)	(0.0723)	(0.0031)
$\hat{\theta}_1$							0.034
$\hat{\theta}_2$							0.015
$\hat{\theta}_3$							0.046

[a] The sum of squares of residuals, SSR_j, $j = 0, 1, 21, 22$, comes from the following four regressions, respectively: $q_t = \nu + \sum_{i=1}^{3} \alpha_i q_{t-i} + u_{0t}$, $q_t = \nu + \sum_{i=1}^{3} \alpha_i q_{t-i} + \sum_{i=1}^{3} \beta_i r_{t-i} + u_{1t}$, $q_t = \nu + \sum_{i=1}^{3} \alpha_i q_{t-i} + \sum_{i=1}^{3} \beta_i r_{t-i} + \sum_{i=1}^{3} \gamma_i \mathrm{I}_{(-\infty,0]}(\Delta r_{t-i}) + u_{21t}$ and $q_t = \nu + \sum_{i=1}^{3} \alpha_i q_{t-i} + \sum_{i=1}^{3} \beta_i r_{t-i} + \sum_{i=1}^{3} \gamma_i \mathrm{I}_{[\theta_i,\infty)}(|\Delta r_{t-i}|) + u_{22t}$.

[b] The likelihood ratio statistics are calculated as $TS_1 = (115-2\times3-1)\times(SSR_1-SSR_0)/(3\times SSR_1)$, $TS_{21} = (115-3\times3-1)\times(SSR_{21}-SSR_1)/(3\times SSR_{21})$ and $TS_{22} = (115-3\times3-1)\times(SSR_{22}-SSR_1)/(3\times SSR_{22})$.

The results of tests for Granger-causality summarized in Table 3 show that the null hypothesis of Granger-noncausality from stock returns to real activity can be rejected at 99% significance level (p-value $= 0.0057$). This means that the expectation

[9] The number of $\Delta r_t \in [min\{|\Delta r_t|\},\ 0.001)$ and of $\Delta r_t \in (0.01,\ max\{|\Delta r_t|\}]$ is 9 for both cases.

of the future real activity in the stock market may be regarded as highly rational —in the sense that the expectation and the realization match well— as long as the expectations are not beyond three quarters. On the other hand, the test for asymmetric Granger-causality shows that the null hypothesis of *Granger-causality but not asymmetric Granger-causality* with the asymmetric term (2) cannot be accepted at 90% significance level (p-value = 0.0723), while the same cannot be accepted at 99% significance level (p-value = 0.0031) with the asymmetric term (3).[10]

4 Concluding remarks

The empirical evidence of the German data found in this paper confirms the proxy hypothesis of Fama (1981) and the indicative role of stock returns on the real activity also reported by Fama (1981), Geske and Roll (1983) and Lee (1992). The findings in the paper also extend the negative correlation of stock returns and inflation and the indicative role of stock returns on the real activity in an asymmetric manner of causality. The asymmetric features are different in the two regressions: in the return-inflation regression the sign of changes of inflation rates plays the key role, while in the return-GDP regression the absolute magnitude of changes of the growth rates of GDP does.

[10]Because of the time trend in the GDP series, the first difference of the growth rates of GDP usually shows more the positive than negative growth rates and the magnitude of positive growth rates are also usually larger than those of the negative. From this point of view one can modify the asymmetric feature in (3) into $\Phi = \{\Delta x_t | \Delta x_t \in [\theta, \infty)\}$, i.e. without absolute value operator. With this type of asymmetry we obtain the value of likelihood ratio statistic in (11) as 4.3759 (p-value = 0.0061), which is a little lower than that of the case in (3).

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