Testing Fisher's Hypothesis for Agriculture

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Abstract

Fisher's hypothesis (or effect), which states that changes in inflationary expectations result in changes of equivalent magnitude and direction in nominal interest rates, is measured for a vector of three interest rates series on different farm loans by commercial banks for three Federal Reserve districts over the period 1978 through 1989. Estimated dynamic sensitivity parameters (DSPs) suggested that a 1 percent (or 100 basis points) increase in expected inflation resulted in a long-run increase in farm loan rates ranging from 41 to 58 basis points which continued over a period of up to 2.5 years. All rates in all three markets converged toward a final cumulative response (DSP) of about 0.50. Within-region responses of different loan-types were more similar than across region responses of similar loan-types given the same sized inflationary shock. In addition, longer-term nominal rates were found to be less responsive than shorter-term rates to inflationary shocks.

Key terms: Fisher's hypothesis; Vector autoregression; dynamic sensitivity parameters.

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Testing Fisher's Hypothesis for Agriculture

Fisher hypothesized that changes in inflationary expectations would result in changes of equivalent magnitude and direction in nominal interest rates. Previous research, which related different measures of inflationary expectations to various government and corporate bond rates, generally concluded that changes in inflationary expectations resulted in positive but less than equivalent changes in nominal rates.

The purpose of this paper is to test the relevance of Fisher's hypothesis for a vector of nominal interest rates on different types of agricultural loans for three Federal Reserve districts (Chicago, Richmond, and Kansas City). Vector autoregression (VAR) econometrics will be used to measure the degree to which Fisher's hypothesis holds for these three regions (or credit markets) during the period considered. The long-run effects resulting from shocks in inflationary expectations on the interest rates of different loan-types within the same credit market will be contrasted. Dynamic sensitivity parameters are calculated in order that the long-run responses of similar loan-types to changes in expected inflation might be contrasted across credit markets.

Fisher's Hypothesis

Fisher's equation is summarized as equation 1 and rearranged as equation 2:

$$\frac{(1+r_n)}{(1+E(i))} = (1+(E)r_r), \tag{1}$$

$$r_n = E(r_r) + E(i) + [E(r_r)E(i))]. \tag{2}$$

Equation 2, also known as Fisher's relationship, state that the nominal rate of interest r_n depends upon the expected real rate of return to assets $E(r_r)$ plus an inflation premium $E(i)$ for the inflation expected for the period of the loan plus their cross-product. Fisher believed that the expected real rate was constant over time and that the cross-product term was insignificant (Fama). Fisher hypothesized that any changes in nominal rates would result solely from changes in expected inflation. Therefore, these changes in nominal rates would be equivalent in both magnitude and direction with and resulting from the changes occurring in inflationary expectations. This last statement has become known as the Fisherian effect.

Fisher said that loans are priced based upon the expected real rate of interest rather than the loan's nominal rate. When inflationary expections are altered, only an identical change in nominal rates can preserve the expected real rate, provided that expected real rates are independent of inflationary expectations (Taylor).

Subsequent developments in the theory of nominal rates have suggested that rather than being constant, the expected real rate varies somewhat over time and is in fact partially dependent upon changes in inflationary expectations. Three different theories (the wealth, income, and depreciation tax effects) hold that the expected real rate is inversely related to inflationary expectations. The first two theories maintain that changes in the expected inflation rate, by changing income or real wealth, change the supply of loanable funds, thereby changing the market-clearing expected real rate. The depreciation tax viewpoint holds that historical cost depreciation rules for tax computations reduce after-tax real returns when expected inflation increases, decreasing the demand for loan funds and thus lowering the after-tax real return expected on potential investment projects (Rose; Taylor). Changes in nominal rates resulting from changes in expected inflation would thereby be offset by changes in expected real rates.

Another theory holds that due to the progressive nature of federal income taxes, nominal rates must change by more than the changes in expected inflation in order to hold the after-tax real rate constant. Under this scenario, changes in expected real rates are positively related to changes in expected inflation and therefore a greater than one-for-one effect between changes in nominal rates and expected inflation would be observed (Rose; Taylor).

Previous Research

Fisher's empirical results suggested the response of long-term bond yields and 4- to 6-month prime commercial paper rates to changes in expected inflation were positive but less than equivalent. Sargent, using a dynamic linear macroeconomic model, showed that an increase in expected inflation would, over periods up to ten years or longer, eventually drive up nominal rates by an equivalent amount. Gibson showed that the adjustment of nominal rates (market yields on Treasury securities, commercial paper, and corporate bond yields) had evolved toward unity from 1952 through 1965. Fama (1975), examining 1- to 6-month U.S. T-Bills over 1953-1971, concluded that all variation in nominal rates had fully and immediately reflected the variation in expected inflation. Friedman, using simulation over six major lender categories, showed that nominal long-term new-issue yields on corporate bonds on the average rose 0.65 percent for each 1 percent rise in expected inflation up to a substantial time lag (four years). Urich and Wachtel showed that an unanticipated increase of one-standard-deviation in expected inflation resulted in an immediate but lesser increase in 6- to 12-month T-Bill rates. MacDonald and Murphy, using cointegration techniques, found no statistical evidence for the existence of Fisher's hypothesis for the United States, Canada, Belgium, and the United Kingdom over the period 1955-1986. Gallagher, using a within-sample Granger-Wald causality test for a Fisherian relationship, showed a feedback relationship between inflationary expectations and U.S. quarterly nominal post-tax interest rates over the period 1953-1978. Atkins, estimating error-correction models for the U.S. and Canadian economies, showed a Fisherian relationship between post-tax nominal interest rates and the inflation rate.

In summary, past research on nominal interest rates for U.S. government (T-Bills) and corporate loans (commercial paper and corporate bonds) generally showed a positive, less than or equivalent response to shocks in inflationary expectations. And that the interest rate response to an inflationary shock continues over several years in duration. Most of the studies inferred that the less than equivalent response in nominal interest rates was due to offsetting changes resulting from the expected real rate's negative response to the same inflationary shock.

Overview of the Variables

This study measures or estimates the degree to which the Fisherian effect holds for a system of agricultural loans for three different Federal Reserve Bank regions. Thus, the primary issue considered is: are changes in nominal interest rates in the same direction and equivalent in magnitude to changes in inflationary expectations? In addition, other issues addressed were: do different loan-types within the same region respond similarly in magnitude, timing, and pattern to equivalent shocks in inflationary expectations? Do similar loan-types in different regions respond similarly in magnitude, timing, and pattern to equivalent shocks in expected inflation?

We examined the relationship between changes in inflationary expectations and three series of average quarterly nominal interest rates on new farm loans for the period 1978:1 through 1989:4 for three different Federal Reserve districts: Chicago, Kansas City, and Richmond. The 7th (Chicago) Federal Reserve district includes: Illinois, Indiana, Iowa, Michigan, and Wisconsin. The 10th Federal Reserve District (Kansas City) includes: Colorado, Kansas, Missouri, Nebraska, New Mexico, Oklahoma, and Wyoming. The 5th Federal Reserve District (Richmond) includes: Maryland, North Carolina, South Carolina, Virginia, and West Virginia.

The three interest rate series common to all three regions which were considered were: feeder cattle loans (FCL), other operating loans (OOL), and long-term real estate loans (REL). The quarterly interest rate survey data were obtained from the Federal Reserve Board's Agricultural Finance Databook. The interest rate survey began in the third quarter of 1975. The series represent the most common interest rate charged on new farm loans (average, percent) by member agricultural banks at the end of the particular quarter.

Since Fisher's hypothesis relates nominal interest rates to expected inflation, a series of quarterly forecasted inflation rates was generated. Here, the naive model uses the percentage change in the forecasted quarterly Consumer Price Index (CPI) series as the proxy for the unobservable expected rate of inflation. The idea is that borrowers and lenders form their expectations of future price levels on the basis of the most recently observed values. This suggests that the optimal forecast for all future quarters' CPI is the present quarter's CPI. However, the present quarter's (t) CPI was unknown to borrowers and lenders when interest rates for the present quarter were determined. Therefore the previous quarter's (t-1) CPI is used as the present quarter's (t) forecast for all future periods CPI. In this manner, a series of forecasted levels of CPI is generated over the estimation period (1978:1-1989:4). The Dickey-Fuller (DF), the Augmented Dickey-Fuller (ADF), and the Durbin-Watson (DW) stationarity tests did not reject the null hypothesis that the logged values of the forecasted quarterly CPI series were a random walk over this period. Thus the use of this simple expectations mechanism (which is often used as a standard by which more complicated forecast models are judged) was not implausible over this period.

In order to convert this series of forecasted levels of CPI into a series of forecasted rates of inflation, first the forecasted levels of CPI are transformed into their natural logarithmic counterparts (LCPI). This new series is used when identifying and estimating the three VAR models. Following the construction of the three VAR models, the impulse responses for each of the four variables (LCPI, FCL, OOL, and REL) in each of the three VAR systems is then estimated. It is the series of impulse responses of the LCPI which proxy for the series of unobservable changes in expected inflation. Within each individual VAR, the impulses of the LCPI will be contrasted to those of the nominal interest rates in order to estimate the degree of the Fisherian effect in each of the three regions.

The Three Estimated VAR Systems

Vector autoregression (VAR) involves a multi-variate system in which each of the system's variables is allowed to influence every other variable in the system with lags. VAR allows characterizing a dynamic system without forcing a priori particular patterns of interactions among the variable set. The method may be considered as a first step in describing the average behavior of the system over the observation period (Bessler).

Three VAR models were estimated over the period 1978:1-1989:4 using ordinary least squares, one VAR for each of the three regions:

$$X_t = a_{x,t} + a_{x,T}TRD + \sum_{i=1}^{N} a_{x,i}LCPI_{t-i} + \sum_{i=1}^{N} b_{x,i}FCL_{t-i} + \sum_{i=1}^{N} c_{x,i}OOL_{t-i} + \sum_{i=1}^{N} d_{x,i}REL_{t-i} + e_{x,t} \quad (3)$$

where X = LCPI, FCL, OOL, and REL (defined above); $a_{x,t}$ the estimated intercept term and a, b, c, and d are estimated regression coefficients. TRD is a time trend variable. The "t-i" subscripts represent particular periods of time (quarters) and $e_{x,t}$ the estimated stochastic error term (or innovation) for period t. "N" represents the lag order of the VAR for each of the three regions. There are four equations of (3)'s form in each of the three separate VARs, one equation for each of the four modeled variables (for an overview of VAR see Sims). Durbin-Watson as well as the estimated Ljung-Box Q-statistic suggests white-noise residuals for each equation in all three VARs.

Results from Tiao's and Box's likelihood ratio tests (not reported here), conducted at the one-percent significance level, suggested a 4-order lag (i.e., N=4) for the Kansas City VAR, a 2-order lag for the Richmond VAR, and a 3-order lag for the Chicago VAR.

The possibility exists that the innovations (residuals) of a VAR's equations may be contemporaneously correlated. Failure to correct for contemporaneous correlation may result in impulse response patterns which are not representative of past historical patterns (Sims). Therefore, a Choleski decomposition was imposed on each of the three VARs, orthogonalizing the current innovation matrix, resulting in a covariance matrix of the modeled innovations equal to identity. This should resolve any potential problems related to contemporaneous feedback.

Choleski decompositions involve imposition of a Wold causal ordering on the VAR model. VAR orderings usually begin with the shock variable, and then order the VAR variables on the a priori belief of the sequence in time over which a line of causality will have the variables respond to each other. Since no a priori reason exists as to which interest rates would precede the other in the Wold causal chain, the VAR orders the FCL, OOL, and REL on the basis of term-to-maturity.

The impulse response function is a technical operation which can be performed over an estimated VAR. The impulse response function simulates over time the effect of a shock in one series on itself and on the other series in the VAR system. Hence, the impulse response function is well-suited for consideration of the issues raised by Fisher's theory in that it allows contrasting the size, immediacy, duration, and direction of responses in nominal interest rates to a shock in inflationary expectations.

A one-time-only, first-period shock (increase) in the innovation of the LCPI is imposed on each of the three VARs. Each of the three VARs is subjected to the same sized initial period shock. The LCPI shock was chosen to represent a one percent rise in the (nonlogged) forecasted CPI, i.e., a one point increase in expected inflation.

Kloek and Van Dijk's Monte Carlo method is used to obtain a t-value in order to test for the statistical significance of each impulse. The highlighted (solid) impulses are statistically nonzero at the five percent significance level, and are herein emphasized.

A dynamic multiplier or sensitivity parameter (DSP) may be calculated with the statistically nonzero VAR impulses (Babula and Romain). Recall that each VAR equation is a function of a particular number of lags (specified by the Tiao-Box tests) of all four modeled variables. So the imposed LCPI shock, equivalent to a one-percentage point rise in expected inflation, places all four of each VAR's equations into motion. Further, the Kloek-Van Dijk results suggests which impulses are statistically nonzero. Recall further that we modeled LCPI as the natural logarithm levels of CPI forecasts, such that shocks to, and impulses in, LCPI mathematically represent proportional changes in the non-logged CPI forecasts. The LCPI impulses may be converted to percentage points of expected inflation by multiplication by 100.

For a particular rate in a VAR, one calculates the DSP in three steps. First, one sums the rate's impulses (in percentage point terms) over the period for which statistically non-zero impulses were observed, to obtain a cumulative point change in the rate. Second, one sums the corresponding LCPI impulses to obtain a corresponding shock-variable change. Third, one divides the rates's cumulative point change by the corresponding percentage point change in CPI forecasts to obtain the rate's DSP. So the DSP is a dynamic version of the static elasticity concept: it is a percentage change in the responding variable over the percentage change in the shock variable. The DSP provides the percentage point change in the interest rate per point change in the expected rate of inflation, defined for the rate's period of statistically nonzero response. Unlike an elasticity, the DSP is not defined for a point in time, but over the observed rates' period of statistically nonzero responses. Yet the DSP is an elasticity-like and dynamic multiplier which shows the strength of the observed rate's statistically nonzero responses to expected inflation.

Impulse responses are provided in Figures 1, 2, and 3 for the Chicago, Kansas City, and Richmond district models, respectively. Panels a, b, and c provide the district's impulse responses in rates charged on feeder cattle, other operating (farm) loans, and real estate loans, respectively. One compares the dynamic response patterns across a district's three rates by comparing across a row of panels. One compares such patterns for a particular rate across the three districts by comparing "down" a column of panels. Highlighted (solid) impulses are statistically nonzero at the five percent level of significance. Table 1 shows the nine DSPs, one for each of the three interest rates (FCL, OOL, REL) for each of the three districts.

Impulse Responses: Different Loan Rates Within Districts

By examining the FCL, OOL, and REL impulses across each of the three rows, one sees that the agricultural interest rates respond similarly. The three Chicago rates respond immediately; gradually gain in strength; and endure for seven quarters. Table 1's DSP calculations suggest that each percentage point rise in expected inflation elicits from 0.47 to 0.54 of a percent rise in Chicago's interest rates.

Two of the three Kansas City rates (FCL and REL) take a quarter to respond. All three Kansas City rates' responses take on a similar pattern in that impulses gradually strengthen; level off at about the two-year point; and endure for ten to eleven quarters. Table 1 suggests that over the ten to eleven quarter response period, each percentage point rise in expected inflation elicits from 0.41 to 0.45 of a point rise in agricultural interest rates.

Richmond rate impulse responses are also similar. The three Richmond rates' responses gradually rise in strength; level-off in strength after about 1 to 1.25 years; and last for a year and a half. Table 1 suggests that over the six-quarter response period, Richmond's agricultural credit rates respond positively by 0.50-0.58 of a percentage point.

In all three regions, the REL interest rates consistantly have the smaller DSPs, implying that real estate loans are less responsive to inflationary shocks relative to the shorter-term feeder cattle and other operating loans.

Impulse Responses: Similar Loan Rates Across Districts

Consider "column-1" (panels 1a, 2a, 3a), which provide how feeder cattle loan rates respond across the three districts. The FCL impulses in Chicago and Richmond are similar, while Kansas City impulses slightly differ. The FCL rate impulses in Chicago and Richmond are immediate; take on similar shapes; last 6-7 quarters; and respond to each percentage point of expected inflation with 0.54 to 0.58 of a point rise in FCL rates. Kansas City impulses in FCL rates take a quarter longer to respond; endure longer (through quarter 10); and respond 0.45 of a point per rise of expected inflation.

"Column-2" provides how other operating loans respond to the point rise in expected inflation across the three regions. The OOL rate responses for the Chicago and Richmond district are immediate; last for 6-7 quarters; and have each point rise in expected inflation met with from a 0.52-0.57 of a point rise in OOL rates. Kansas City's OOL rates impulses, while also immediate, endure for 2.5 years, about a year longer than the other two Federal Reserve districts. The Kansas City rates respond by 0.45 of a point for each point increase in expected inflation.

"Column-3" provides how REL rates respond to the point rise in expected inflation. The Chicago and Richmond model rates rise immediately; respond for 6-7 quarters; and rise by 0.46-0.50 of a point per point rise in inflationary expectations. The Kansas City impulses in REL rates respond significantly after a 1-quarter delay; continue to significantly respond for 9 quarters (i.e.; through quarter 10); and rise by 0.41 of a percent given a percentage point increase in expected inflation.

Rates for the Chicago and Richmond districts are the most similar in reaction times, shape of response patterns, duration, and in magnitudes of response as implied by the DSPs. In comparison, Kansas City rates are generally slower in responding; are longer lasting; but respond less given a percentage point rise in inflationary expectations.

Discussion

The results herein suggest that the Fisherian effect for farm loan rates and inflationary expectations holds inexactly, at least for the loan-types, regions, and period considered. As Table 1 indicates, all nine DSPs were both positive and less than unity. DSPs ranged from 0.41 to 0.58 and averaged about 0.50. That is, a 1 percent increase in inflationary expectations resulted in a long-run average increase of 0.5 percent in farm interest rates. The statistical evidence that interest rates on farm loans increase in a positive but less than equivalent magnitude given changes in inflationary expectations, and that these responses continue over numerous periods, is consistant with the results of much of past research for goverment and corporate loans.

That the responses for farm interest rates to inflationary shocks (as indicated by the DSPs in Table 1) are less in magnitude than those reported for government and corporate bond research is noteworthy. Previous research (Fama 1981; Geske and Roll) suggested that relationships between stock returns and inflation vary with security risk levels. Following their research, Chang and Pinegar showed that the effect of expected inflation on real stock returns becomes increasingly negative as security risk increased. A more reactive (in a negative sense) real rate would result in a less reactive nominal rate given an inflationary shock. One would expect, therefore, that nominal rates on the relatively riskier farm loans would be less responsive to inflationary shocks than would be observed in government and high-grade corporate loans. Contrasting our responses (DSPs ranging from 0.41 to 0.58) to the responses found by previous research for government and corporate loans (ranging from 0.65 to 1.00) is consistant with this view. Apparently, the decrease in the expected real rate of return on the riskier farm loans resulting from an inflationary shock is greater than that which occurs in the relatively less risky government and corporate loan markets.

Of interest is the consistantly weaker response (in magnitude of effect) of the longer term interest rate (REL) in contrast to those of the shorter term rates (FCL and OOL) noted in all three farm credit markets. These results, a sort of "term-to-maturity effect" with respect to inflationary shocks, are consistant with those found by Huizinga and Mishkin. They found that before 1979 a negative relationship existed between the ex ante real rate on both stocks and bonds with inflation which grew with the maturity of the financial asset. This implies that the longer the term-to-maturity of a financial asset, the less responsive its nominal rate is to an inflationary shock due to the increasingly negative, offsetting response in its expected real rate of return.

The impulse responses of the different interest rates and their respective DSPs indicated certain similarities which were robust in both the within- and across regions. Within all three credit markets, interest rates on different loan-types initially respond to an equal-sized inflationary shock by roughly equivalent magnitudes and follow similar patterns of approach over the same time interval towards similar long-run responses. Apparently, borrowers and lenders within a given credit market incorporate similar inflationary expectations into their different loan-types.

Responses of interest rates (in their magnitudes, patterns, and duration) as well as in the range of their respective DSPs were more similar for different loan-types within the same region than for similar loan-types across regions. This suggests that the incorporation of inflationary expectations into interest rates is more a function of the individual credit market (i.e., the set of borrowers and lenders) in which the rate is set than the particular type of loan.

Conclusions

Fisher's effect was found to hold inexactly for a series of three different farm loan-types in three different credit markets over the period 1978 through 1989. Estimated dynamic sensitivity parameters suggested that a one percent increase in inflationary expectations resulted in a long-run increase (up to 2.5 years) from 41 to 58 basis points in nominal farm interest rates. All interest rates in all three markets converged toward a final long-run response (DSP) of about 0.50. As previous theory and research in non-agricultural markets had suggested, the interest rates on the relatively more risky farm financial assets were found to be relatively less responsive to inflationary shocks than those which had been estimated previously for non-farm interest rates. Furthermore, the relatively weaker responses of the long-term real estate loans for the farm sector is consistant with the result of previous research concerning a term-to-maturity effect in the non-farm sectors. That within-region responses of different loan-types were more similar than across-region reponses of similar loan-types suggest that the manner in which inflationary expectations is incorporated is more a function of the particular observed credit market than the particular type of loan.

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Table 1. Dynamic Sensitivity Parameters (DSPs) for Three Federal Reserve Districts Estimated Over the Period 1978-1989.

	Loans		
	Feeder Cattle	Other Operating	Real Estate
Chicago	0.54	0.52	0.47
Kansas City	0.45	0.45	0.41
Richmond	0.58	0.57	0.50

Note: A particular DSP (e.g. Feeder Cattle for Chicago) may be interpreted as follows: "A one percent shock (increase) in inflationary expectations eventually resulted in a long-run increase of 0.54 percent (or 54 basis points) in nominal interest rates on feeder cattle loans in the 7th (Chicago) Federal Reserve district."