RARE EVENTS AND NEWS IN A RATIONAL EXPECTATIONS ECONOMY

A Master's Thesis

by

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RARE EVENTS AND NEWS IN A RATIONAL EXPECTATIONS ECONOMY

The Institute of Economics and Social Sciences
of
Bilkent University

by

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ANKARA

July 2003

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Economics.

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ABSTRACT

RARE EVENTS AND NEWS IN A RATIONAL EXPECTATIONS ECONOMY

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We examine the effect of inflation risk on a rational expectations monetary economy with endogenous production. The risk that we consider is of a change in the rate money growth from an initial steady-state level to a new level which is selected from a known distribution. The event of policy change is considered to be rare. The inclusion of rare events means that rational expectations does not require deviations of actual from expected inflation to be of zero mean or to be serially uncorrelated. We view the probability of a policy change, and the distribution of ensuing policy parameters as potentially changing over time. This highlights the role of News in determining the equilibrium of the economy. In the absence of any actual real or monetary shocks, changes in the perception about the likelihood and severity of a rare event have price, real and distributional effects.

We find that inflation risk has price, real, and distributional effects.A risk of higher inflation increases the equilibrium price level and nominal interest rates. Inflation risk induces an increase in capital investment and production, and reduces the steady-state rate of return on equity. If the policy does not actually change, the ex-post real interest rate increases. The change in rates of return leads to a redistribution of wealth away from borrowers of nominal instruments towards lenders. Also we find that the theoretical second moment of future money growth has (almost) no effects on the economy.

Keywords: Inflation risk, News, Monetary economy.

ÖZET

RASYONEL BEKLENTİLERİ OLAN BİR EKONOMİDE NADİR OLAYLAR VE HABERLER

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İçsel üretimi olan rasyonel beklentilere sahip parasal bir ekonomide enflasyon riskinin etkilerini inceledik. Kullandığımız risk parasal büyüme oranının başlangıçtaki durağan durumundan bilinen bir dağılımdan seçilen yeni bir duruma doğru değişmesidir. Politika değişikliği nadir görülen bir olay olarak kabul edilir. Nadir olayların kapsadığı anlam: rasyonel beklentilerin gerçek enflasyonun beklenen enflasyondan sapmalarının sıfır ortalamaya sahip olmasını veya seri olarak aralarında korelasyon olmamasını gerektirmemesi durumudur. Politika değişikliği olasılığının ve izleyen politika parametrelerinin dağılımının zaman içinde potansiyel olarak değiştiğini gördük. Bu, haberlerin ekonominin dengesini belirlemedeki rolünün önemini vurgular. Gerçek bir reel veya parasal şokun olmadığı durumda nadir bir olayın ciddiyeti ve olasılığı hakkındaki algılamanın değişmesinin fiyat , reel ve dağılımsal etkileri vardır.

Enflasyon riskinin fiyat, reel ve dağılımsal etkilerinin olduğunu bulduk. Yüksek enflasyon riski denge fiyatını ve nominal faiz oranlarını yükseltir. Enflasyon riski sermaye yatırımının ve üretimin artmasına öncülük eder ve özsermayenin durağan durum getiri oranını azaltır. Politika gerçekten değişmemişse gerçekleşen faiz oranları artar. Getiri oranınındaki değişme servetin nominal senetleri borçlananlardan borç verenlere doğru yeniden dağıtılmasına öncülük eder. Ayrıca gelecek parasal büyümenin teorik ikinci momentinin ekonomi üzerinde neredeyse hiç etkisinin olmadığını bulduk.

Anahtar Kelimeler: Enflasyon riski, Haberler, Parasal ekonomi.

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1 Introduction

Developing countries' economies in particular are subject to rare events of significant economic importance. Possible events include, but are not restricted to, exchange rate devaluation, debt default, a significant increase in inflation, banking crises, capital flight, and labor disruption. While not perfectly foreseable, the likelihood of an event can be perceived by economic agents. Therefore news about political or economic events affect agents perceptions and behavior.

In this paper we focus on one type of risk in an otherwise stable economy; the risk of changing money growth rate policy regime. This change could be to a higher or to a lower rate of inflation than the current rate, though we will focus on the former case.

According to Milton Friedman, regime uncertainty is an important source of inflation uncertainty. In his 1976 Nobel Lecture, Friedman argued that inflation uncertainty affects the trade-off between inflation and unemployment because inflation volatility and uncertainty "render market prices a less-efficient system for coordinating economic activity" (1977, p. 467). He also asserted that inflation regime uncertainty may be considered as the underlying source of the observed positive relationship between inflation rates and inflation volatility. He added that it takes several decades for people to learn about the new regime and to adjust their expectations about whether the old regime will recur. According to Friedman (1977) uncertainty about policy regime changes decreases real economic activity.

Evans and Wachtel (1993) find that uncertainty about future inflation process influences unemployment even after accounting for the effects of inflation and monetary policy. Their claim is that uncertainty about inflation regimes is a source of inflation uncertainty. They find that increased uncertainty about inflation regimes leads unemployment to rise but uncertainty about other types of inflation shocks has no effects on unemployment. They find little evidence that inflation uncertainty influences real economic activity negatively. For the periods of two or three years uncertainty about future inflation rate significantly affects unemployment while short-term uncertainty has less effect.

The motive for this study is to examine the effect of inflation risk in the times that it is not realized. If a developing country experiences an unexpected jump in the inflation rate every ten years, on average, the risk of this occurrence will affect prices and behavior in the ensuing period. This highlights the effect of news on the economy. News which changes people's perception the probability of moving to a higher inflation rate regime will affect prices and behavior in the absence of any actual real or monetary shock.

It is then possible that news affecting agents expectations about potential, but unrealised and maybe never realised events, may be as much as a driving force as the real and nominal disturbances routinely incorporated into dynamic general equilibrium macroeconomic models.

1.1 The Approach

This paper examines the role of inflation risk in a production economy with variable velocity of money. In this economy, money is neutral and is superneutral with respect to output, investment and labor hours.

The notion of risk is as follows: The country is initially in a steady-state equilibrium with no output growth and a constant money growth rate. We introduce a small probability that the money growth rate policy makes a permanent change to a new level which is selected from a given distribution. We then examine the effect of this risk on the economy. We find price effects, real effects and distributional effects. Expectations are formed according to the Muthian proposition "that expectations, since they are informed predictions about future events, are especially the same as the predictions of the relevant economic theory" (Muth 1961, p. 316). Although not studied here, we can envision the probabilities as changing on a regular basis due to changes in political and economic conditions. This view lends a role for "news" to affect prices, output and returns. It is a possibility that changes in perceived risk have as much effect as actual changes in the exogenous variables.

1.2 Overview of Results

Even though output is superneutral with respect to the inflation rate, the introduction of risk concerning the future money growth rate, hence the inflation rate, induces real changes in output, investment, and labor hours. We find that, introducing a chance of higher future inflation increases the equilibrium capital stock, output and labor hours. This results from the Cagan effect. Higher inflation, if realized, would result in 1) reduced demand for real balances, 2) a higher velocity of money, and 3) a higher price level. The chance of moving to a higher price level increases the expected return on the physical asset, capital; so more capital is accumulated in equilibrium. This reduces the returns to physical capital investment. This conforms to empirical evidence, which finds a negative correlation between inflation and stock returns

We find that mean preserving increases in the inflation rate have no real effects. A high theoretical variance does not affect the capital stock, labor input or output level. Lee and Ni (1995) mention that the method of measurement of inflation uncertainty has importance for determining the impacts of inflation uncertainty on real activities and they indicate a highly significant negative correlation between real activities and inflation uncertainty measured by a state dependent conditional variance model. Lee (1999) uses inflation conditional variance to measure inflation uncertainty. When inflation uncertainty increases, future real earnings on investment will be more uncertain. This uncertainty reduces current investment and output. He finds a strong negative correlation between inflation conditional variances and real returns. Sweeney (1987) finds that an increase in variance of inflation rate by itself makes capital more attractive relative to real balances and increases capital stock. According to Logue and Sweeney (1981) changes in variance of inflation rate and variance of real disturbances are highly correlated. Based on this idea in Sweeney (1987) proportionate rises in both variances reduce both capital stock and full-employment real output on balance.

2 Literature Survey

Boyle (1990) finds that monetary shocks have no real effects in his dynamic asset-pricing model where output and money are exogenously determined. However, changes in people's expectations do have real effects. When expectations change, the expected future purchasing power of money balances also changes. In response to a change in the expected money growth rate, velocity increases and leading to an increase in real stock prices. Therefore, their expected returns to equity increase.

Carmichael (1989) argues that expected monetary policy can have real impacts by affecting expectations about inflation. When a permanent increase in the growth rate of money supply is announced by the government in advance, the price level increases before the implementation of the policy because consumers know that the price level will be higher and they want to avoid the capital loss on their money holdings, they adjust their expenditures before new policy implementation. This creates a force on the goods market. It is argued that the actual change in the money supply is non-neutral if the change is expected in advance. If a change in money supply is unexpected there will be no effect on the economy's equilibrium except for the fall of ex-post real return on bonds, money and equity. In the empirical study it is found that most of the adjustment of the price level is achieved before money starts growing at a faster rate. This finding is in contrast to the findings of Helpman and Razin (1982) who claim that expected monetary policies influence price level only after the money stock is changed.

Taylor (1975) argues that monetary policy can affect real economic variables during the transition periods in which economic agents combine new information with old information to form new beliefs. In these periods, contrary to the rational expectations assumption, people's optimal predictions of the inflation rates act like adaptive expectations and monetary authorities can attain a desired level of a real variable by deciding an appropriate time path for policy.

Marshall (1992) examines the correlation between asset returns and inflation in a monetary asset-pricing model. His model is consistent with the post-war U.S. data, which displays negative correlations between real equity returns and inflation. He finds a stronger negative correlation between asset returns and inflation when inflation is caused by fluctuations in real economic activity rather than when it is caused by monetary fluctuations.

West (1988) uses a stock price volatility test to examine stock price changes and finds that stock prices can not simply be the expected present discounted value of dividends with a constant discount rate because stock prices are too volatile. According to his results, discount rates change and discount rate fluctuations can not be attributed to excess variability of stock prices. Excess volatility does not come from the failure of the rational expectations or constant discount rate assumptions but the volatility comes from either rational bubbles or nearly rational "fads" whose profit opportunities are difficult to detect.

Boudoukh, Richardson and Whitelaw (1994) examine the cross-sectional relationship between stock returns and inflation. Most of the empirical findings support the idea that there is a negative relationship between stock returns and both expected and realized inflation rates. This negative relation is especially surprising for stocks, which are considered as compensation for the movements in inflation. In this study a negative relationship between stock returns and inflation at short horizons is found and a positive relation at long horizons is obtained. For noncyclical industries such as food and beverage, tobacco, and utilities, stock returns are positively related to expected inflation. On the other hand, for cyclical industries, such as metal products and petroleum products, machinery, and equipment industries, there is a negative relationship between stock returns and expected inflation. There exists a reliable cross-sectional variation in the relations across industries.

Refett (1996) focuses on the asset return anomalies engendered by inflation and money in monetary economies and indicates that these anomalies change the structure of risk prices in a capital asset pricing model. According to the study transaction costs are considered to be an important source of distortions in risk prices.

Under the rational expectation hypothesis, forecast errors are predicted to be uncorrelated with the information set used to form the forecasts and to have zero mean. Lewis (1989) observes that systematic forecast errors occurred in the U.S. money market in the early 1980s. One possible explanation is irrationality on the part of market actors. Lewis brings a different explanation. Observing that there had been a structural shift in monetary policy, economic agents did not immediately believe that this shift was permanent but they learned the change in fundamental process over time and revised their beliefs about the process. Lewis concludes that systematic forecast errors come from the learning behavior of agents with expectations of future policy changes and risk premia.

Flood and Garber (1980) imply that the rational expectations hypothesis provides a structural relationship between actual and expected price changes based on the knowledge of agents about market fundamentals. However, if the expected market price is important in forming the actual price and if the expectations about market price are arbitrary and self-fulfilling then actual price moves independent of market fundamentals and price bubbles occur.

Salyer (1990) studied the term structure of nominal interest rates. Most of the term structure literature shares a common belief of a failure of the rational expectations hypothesis. The data indicates that the term premium varies over time and any theory about term structure proposed as a replacement for expectations hypothesis has a potential for generating a time varying term premium. In the study based on the Lucas's (1982) cash-in-advance model, a one-and-two-period nominal interest rate model is developed in order to answer the question of whether the model is consistent with that exhibited in the data. Although the model is consistent with some broad empirical characterizations, it fails to explain the behavior of the term premium.

Evans and Lewis (1995) investigate the long run relationship between inflation and nominal interest rates. The estimates indicate that inflation moves less than one-for-one with nominal interest rates due to the changes in dynamics of the inflation process. The findings imply that ex-ante real rates are subject to permanent shocks and these shocks are shared by expected inflation. This permanent shocks come from the fact that people embed expected shifts in inflation process into their expectations. A markov-switching model of inflation is set which captures the structural shifts in the inflation process. Results based on this model indicate that there is a long run relationship between nominal interest rates and inflation. Elliott (1977) models real interest rates using different rational expectations models of the real interest rate based on the neo-keynesian and loanable fund methods. These methods are alternative to Fisher type of real interest rate model where it is assumed that expected real interest rates are constant over time. Fisher's interest rate model is not useful because estimation of expected inflation rate depends on the long lags of price level.

According to the neo-classical loanable funds theory, current real income does not depend on the current interest rates and prices. However, interest rate movements are important in dividing current real income into consumption and investment flows while regulating the money capital flows through financial markets. They find that the expected real interest rate is independent of current real output levels. A statistically significant negative relationship between the temporal pattern of the real interest rate and the current actual rate of inflation is found. A neo-Keynesian model with a monetary explanation of expected inflation rate is found as the most efficient model for the measurement of the expected real interest rate. The calculated expected real interest rate is an unbiased estimate of ex-post real rate, subject to substantial short run shifts over time and not correlated with real output.

Dotsey and Ireland (1995) focus on the liquidity effects—a reduction in the short-term interest rate and a rise in output and employment—in response to an increase in money supply. A positive monetary shock increases interest rates when transactions costs are low. Firms desire to hire less labor because of the inflation tax so wage payments decline. To offset lower wages, households decrease their savings to smooth consumption, which entails higher transaction balances. As transactions cost increase in response to positive monetary shock, people transfer fewer money balances from their savings accounts and interest rates declines when transaction costs are higher. The model finds that when marginal transaction costs are large, liquidity effects continue to dominate, and in response to an unexpected monetary expansion interest rates fall and hours worked increase, while in small or moderate marginal transaction costs, liquidity effects are either eliminated or dampened by the expected inflation effects and the response of interest rate to the surprise monetary expansion is positive.

Ferderer and Zalewski (1994) focus on interest rate uncertainty. They measure interest rate uncertainty by including a risk premium in the interest rate structure. They use forward rate risk premium as a proxy for the risk premium. Even if the risk premium is small and economically insignificant, changes in the risk premium give important information about uncertainty, which affects financial markets. The study indicates that interest rate volatility has a significant and positive effect on the risk premium and stock return volatility has a positive but insignificant effect on the risk premium. The weak link between stock return volatility and the risk premium is results from the different type of uncertainty that influences each variable. Stock return volatility is affected by the uncertainty about future income flows more than by interest rate uncertainty, while the risk premium is affected by nominal interest rate uncertainty. There is also a positive relationship between discount rate volatility and the risk premium.

Eichengreen (1992) argues that increased interest rate uncertainty due to the banking crises and collapse of the international gold standard in the early 1930s exacerbated the severity of the Great Depression. He finds that the risk premium explains an important part of the variation in aggregate investment spending during the Great Depression.

Ruefli (1990) investigates the mean-variance approaches to risk-return relationship. In this study, it is found that when the mean and variance of return are used, the results are common only for the period and data that are examined, they can not be generalized for all data and periods because it is impossible to identify the underlined reason of the mean-variance relationship. The relation may come from either any movements along a mean-variance curve or shifts in some unspecified relationship between two variables in some sub periods.

Love and Wen (1999) analyze the cost of inflation in a monetary endogenous growth model where money reduces the time costs of transactions. According to analytic results, there is a negative effect of inflation on long run growth rates and substantial welfare costs come from inflation and long run growth effects of inflation. When inflation is higher, returns to money becomes lower and people reduces their transactions balances by substituting time for money, and time costs increase. Increased time costs lead labor supply to decrease, which results for reducing returns to capital, declining accumulation and long run growth.

Hoffman and Schlagenhauf (1985) develop various spot exchange rate models in a news framework, to measure the impact of news on foreign exchange rate movements. News is introduced to the model as unexpected shocks in explanatory variables. The explanatory variables that are linked to the exchange rate, are determined according to theory and in several exchange rate models, a wider set of variables are examined in news form. Although their study does not find a strong evidence for the correlation between monetary shocks and exchange rates, both quarterly and monthly data find negative relationship between income shocks and exchange rate.

Edwards (1983) focuses on the impacts of unexpected changes in the deteminanats of exchange rate, or news, on the spot rate. He examines the relationship between forward exchange rates, future spot rates and new information. Effects of unexpected changes in money supply, real income and real interest rates are considered and altough the emprical results suggest that new information about exchange rate determinants play an important role in explaining exchange rate behavior, there are some other elements, rather than news, which affect exchange rate behavior. According to the model, news about a permanent increase in the domestic quantity of money has a positive effect on the spot rate and news about unexpected increases in real income has negative effects on the difference between the spot rate and the forward rate. News about unexpected changes in real interest rate has a negative effect on the difference between the spot rate and the forward rate.

Another attempt to measure the impact of the news on foreign exchange movement comes from Hartley (1982). He uses maximum likelihood estimator to analyze a simple monetary model and an *ad hoc* interest rate model. According to the study, an unexpected change in the money stock gives more information than the unexpected change in interest rates if monetary authorities follow a money stock growth rate rule .

3 The Model

We examine a closed monetary economy with endogenous production. This model has three sectors: government, firm and consumer. Capital and labor produce the single output using a Cobb-Douglas production function. Money is introduced via a cash-in-advance constraint place upon consumption purchases. The velocity of money is determined in the model and is allowed to vary in response to changes in inflation rate. The consumer faces a trade-off between holding money, which has no nominal return, and obtaining currency more frequently through a costly transaction. There is a trade-off between the average real balance and the velocity of money. The cost is made explicit in a kind of production function for the velocity of money. The consumer owns a share of the firm. The firm pays dividends consisting of revenue less capital accumulation cost and wage payments.

In this study, the government has no function other than supplying money to the economy via lump-sum transfer payments. The firm's role is providing the economy with output using Cobb-Douglas production function. The consumer's problem is to maximize his utility function subject to his budget constraint and cash-in-advance constraint while the firm tries to maximize its profit with respect to current labor and future capital stock. After defining equilibrium conditions for market to clear and stationary representations of consumer's constraints, we derive the consumer's first order conditions. The risk-free equilibrium represents the combination of optimization conditions of the consumer and firm, together with the market clearing conditions and from table 1 the relationships among variables in absence of risk can be examined.

3.1 The Government

The government's sole role is to supply the economy with money via lump-sum transfer payments. The money supply evolves according to $\overline{M}' = \omega' \cdot \overline{M}$ [1] where ω is the growth rate of money balances. The government's budget constraint is:

$(1+i)^{-1} B' = B - (\omega - 1)\overline{M} + T$, where T is the transfer payment or tax and B represents nominal bond supply. The one period bonds are sold on a discounted basis. Without the loss of generality we can assume $B' = B = 0$.

3.2 The Firm

Output is produced using a Cobb-Douglas production function using capital, *K*, and labor, *L*, as inputs:

$$Y = K^{\theta} L^{1-\theta} \tag{1}$$

All markets are competitive. The firm owns its capital stock and the firm, in turn, is owned by the representative consumer. The firm pays out dividends to its owners. The dividends, expressed in nominal terms, are assumed to be: $D = P(Y - I) - W \cdot L$, where $P(Y - I)$ is the value of output net of depreciation and $W \cdot L$ is the wage payments. Wage is given by the marginal product of labor: $W = (1-\theta) \cdot \left(\frac{K}{L}\right)^{\theta}$.

[1] We follow the convention where a prime refers to variables in period *t*+1 and no prime refers to variables evaluated at time *t*.

3.3 The Consumer's Problem

The representative consumer has preferences given by:

$$u(c_1, c_2, L) = \alpha \ln c_1 + (1-\alpha)\ln c_2 - \gamma \cdot L \qquad (2)$$

where c_1 is the consumption of the "cash good", c_2 is the consumption of "credit good", and α is the relative weight given to the consumption of the cash good in the utility function. Labor enters in the utility function linearly and γ is the marginal disutility of labor.

The consumer is subject to two constraints. The budget constraint is given by:

$$P(c_1 + c_2 + \tau) + M' + (1+i)^{-1} B' + Q \cdot z' \leq (Q + D) \cdot z + B + M + W \cdot L + T . \qquad (3)$$

The right hand side gives the resources available to the consumer. These resources are firm equity and dividend payment, $(Q + D) \cdot z$, where z is the consumer's ownership share, Q is the nominal equity value of the firm, and D is the current dividend payment, nominal government bonds, nominal money carried from the previous period, wage payments, and any lump sum transfer payment from the government paid in the form of currency or government bonds. The left hand side shows where the consumer spends his wealth. Current consumption is in the form of a cash good and credit good and τ which represents resources dedicated to transacting. It can be seen as a shoe-leather expense. Saving takes the form of nominal money balances, discounted government bonds and an ownership share of the firm.

The consumer is also subject to a cash-in-advance constraint on consumption of the cash good, c_1. This creates a demand for money, even though money is dominated in return by bonds and equities. The demand for money is motivated by the cash-in advance constraint. It is indicated in equation 4:

$$P \cdot c_1 + \leq M \cdot n . \qquad (4)$$

M is the nominal money balances obtained in each transaction and n is the number of transactions in the data period.

The CIA constraint allows for a variable velocity of money. The choice variable n represents how often the consumer replenishes her money balances. The consumer selects n to balance two costs. As n increases, the consumer can save on holding real money balances, the opportunity cost of holding money is the nominal interest rate. On the other hand, increasing n increases the transactions cost. We chose the following simple transactions technology:

$$n = \phi \cdot \tau . \tag{5}$$

The number of transactions per period, n, is proportional to the level of resources devoted to transacting, τ. The parameter ϕ can be interpreted as the inverse of the cost per transaction.

To make the consumer's problem stationary, we divide the two constraints by next period's money stock, $\overline{M}'$, to define these new variables:

$$m' = \frac{M'}{\overline{M}'}, \quad b' = \frac{B'}{\overline{M}'}, \quad p = \frac{P}{\overline{M}'}, \quad q = \frac{Q}{\overline{M}'}, \quad w = \frac{W}{\overline{M}'}, \quad d = \frac{D}{\overline{M}'} \quad t = \frac{T}{\overline{M}'} \tag{6}$$

Here m is the share of money supply held by the representative consumer. In equilibrium this is unity. The other variables, p, q, b, w, d, and t are the real goods price, equity price, bond value, wage, dividend, and transfer payment. In this representation the share of the money stock held by the consumer is selected as a numeraire.

3.4 The Firm's Problem

The firm's problem can be posed as a value function problem:

$$W(\Omega) = \max_{K', L} \left\{ p\left[y + (1-\delta) \cdot K - K'\right] - w \cdot L + \beta \cdot W(\Omega') \right\}. \tag{7}$$

The first order conditions for this problem are given by equations 8 and 9:

$$W_L(\Omega) = -w + p \cdot f_L = 0 \tag{8}$$

$$W_{K'}(\Omega) = -p + \beta \cdot W_{K'}(\Omega') = 0 \qquad W_{K'}(\Omega') = [1 - \delta + f_K] \cdot p \tag{9}$$

Equation 8 implies that the real wage is determined by the marginal product of labor, f_L. Equation 9 determines the marginal product of capital, f_K.

3.5 Equilibrium Conditions

Equation 10 summarizes the equilibrium conditions required for markets to clear:

$$\begin{aligned} z' &= z = 1 \\ m' &= m = 1 \\ b' &= b = 0 \\ c_1 + c_2 + \tau + I &= Y \\ K' &= (1 - \delta)K + I \end{aligned} \tag{10}$$

In equilibrium, the consumer's share of equity, z, and the share of money, m, is one. The net fiscal debt level, b,can be assumed to be zero without the loss of generality. The resource constraint holds with equality, that is, output is equal to the total of consumption, investment as physical capital and resources dedicated to transacting. The last equation shows the law of motion for capital stock.

3.6 The Consumer's Problem

The stationary representation of the consumer's budget constraint is given by equation 11, and equation 12 gives the stationary version of the cash-in-advance constraint.

$$p(c_1 + c_2 + \tau) + m' + (1 + i)^{-1} b' + q \cdot z' = (q + d) \cdot z + \frac{b + m}{\omega} + w \cdot L + t \tag{11}$$

$$p \cdot c_1 = \frac{m \cdot n}{\omega} \tag{12}$$

The consumer's problem can be expressed as a value function problem:

$$v(\Omega) = \max_{c_1, c_2, \tau, L, m', b', z'} \left\{ u(c_1, c_2, L) + \beta \cdot v(\Omega') \right\} \quad (13)$$

subject to equations 11 and 12. The state of the world is described by the vector of variables $\Omega = \langle \omega, B, M, K \rangle$. The choice variables are cash good, credit good, transaction cost, labor supply, future real balances, bond holding, and ownership share of the firm in the next period. The lagrange multiplier for budget constraint is λ and for cash-in-advance constraint is μ.

3.7 The Consumer's First Order Conditions

The consumer's first order conditions are given in equations 14-19:

$$v_1(\Omega) = u_1(c_1, c_2, L) - p \cdot (\lambda + \mu) = 0 \qquad v_2(\Omega) = u_2(c_1, c_2, L) - p \cdot \lambda = 0 \quad (14)$$

$$v_\tau(\Omega) = -p \cdot \lambda + \frac{m \cdot \mu}{\omega} \cdot \phi = 0 \quad (15)$$

$$v_L(\Omega) = u_L(c_1, c_2, L) + w \cdot \lambda = 0 \quad (16)$$

$$v_{m'}(\Omega) = -\lambda + \beta \cdot E[v_{m'}(\Omega')] = 0 \qquad v_m(\Omega) = \frac{1}{\omega}(\lambda + \mu \cdot n) \quad (17)$$

$$v_{b'}(\Omega) = -(1+i)^{-1} \lambda + \beta \cdot E[v_{m'}(\Omega')] = 0 \qquad v_b(\Omega) = \frac{\lambda}{\omega} \quad (18)$$

$$v_{z'}(\Omega) = -q\lambda + \beta \cdot E[v_{z'}(\Omega')] = 0 \qquad v_z(\Omega) = (q + d) \cdot \lambda \quad (19)$$

3.8 Risk-free Equilibrium

Combining the consumer's first order conditions with respect to labor hours, *L*, with the expression of wage, we obtain that consumption of the credit good, c_2, is a fixed proportion of income, net of investment and it is independent of the transaction costs, therefore the inflation rate. While consumption of the cash good, c_1, is reduced by the resources used in transacting. Thus, inflation places an indirect tax upon the credit good since transacting is an increasing function of the inflation rate.

$$c_1 = \alpha(Y - I) - \tau$$
$$c_2 = (1 - \alpha)(Y - I) \tag{20}$$

The price level results from the combination of equations 12 and 20. In equation 12, for, *n*, we put the equation 5 which gives the transaction technology and for, *m*, we put one which is the equilibrium condition for the share of money for the market to clear. We find the equation for price level is:

$$p = \frac{\phi \cdot \tau}{\omega} \left[\alpha(Y - I) - \tau\right]^{-1} \tag{21}$$

Using equation 21, we reach the equation for transaction cost. By combining equations 15 and 16 in the consumer's first order conditions with 21 and eliminating *p* from these equations, we solve transaction cost function, τ, in terms of given parameters. The amount of resources used in transacting, τ, has a square root representation.

$$\tau = \frac{\sqrt{i^2 + 4\alpha\phi(y - I) \cdot i} - i}{2 \cdot \phi} \tag{22}$$

In the equation 22 the variable *i* represents the nominal interest rate, which is found from equation 18 in the consumer's first order conditions. It is a positive function of money growth rate, ω, and describes the Fisher effect. The nominal interest rate is:

$$i = \frac{\omega}{\beta} - 1 \tag{23}$$

From equation 22 it is seen that the amount of resources used in transacting, and hence by equation 5, the number of transactions, and the velocity of money, are increasing functions of the inflation rate and the level of real output.

From equation 9 in the firm's first order conditions we obtain the marginal product of capital. The usual optimality rule for the capital stock applies. The firm gathers capital until the marginal product of capital equals the consumer's rate of time preference, $\beta^{-1}-1$ plus the depreciation rate on capital, δ.

$$f_K = \beta^{-1} - 1 + \delta \tag{24}$$

Equilibrium capital stock and labor hours can be found by iteration.

3.9 Risk-free Results

We will be examining the behavior of this model under inflation risk. We begin by examining the performance of the above equations in the absence of risk. The risk-free optimality conditions can be better understood by looking at Table 1. This relates the equilibrium values of τ, *p*, and *i* as a function of the inflation rate, given by $\omega - 1$. From equation 23 we find that nominal interest rate is a positive function of money growth rate. As the money growth rate increases, the opportunity cost of holding money, the nominal interest rate, increases. It is seen from the equation 22 that the amount of resources used in transacting increases in *i*, therefore the number of transactions increases with the nominal interest rate. So the increase in nominal interest rate induces the consumer to transact more often and reduce the level of real balances. Also we can see a positive relationship between transaction cost and price level by equation 21. In the CIA constraint, equation 4, when the consumer reduces the level of real balances, since the nominal money supply is exogenously determined, the price level must make a one-off increase.This is the Cagan effect. So we see a positive relationship between money velocity and the interest rate.

A key result is that the model is superneutral with respect to the production side variables *Y*, *K*, and *L*. The real rate of return on nominal bonds and on equity are uneffected

TABLE 1
Equilibrium Conditions as a Function of the Inflation Rate
Model Calibrated for M2

Annual Inflation Rate	Number of Transactions per Quarter	Price Level	Annual Velocity	Seigniorage Revenue (%GNP)	Welfare Cost (%GNP)
-4%	0.00	0.00	0.00	- - -	0.0%
0%	0.23	0.30	1.39	0.0%	2.91%
3.24%	0.31	0.41	1.89	0.20%	3.88%
5%	0.34	0.45	2.10	0.27%	4.30%
10%	0.42	0.56	2.62	0.43%	5.29%
20%	0.53	0.71	3.42	0.63%	6.75%
50%	0.75	0.99	5.02	0.99%	9.52%
100%	0.95	1.23	6.70	1.31%	12.22%

Table 1 is based upon the model calibrated to represent U.S. quarterly data using the following parameter values.

$\theta = 0.36$ - share of capital in output

$\delta = 0.02$ - quarterly depreciation rate

$\beta = 0.99$ - discount factor

$\gamma = 1.80$ - marginal disutility of labor

$\alpha = 0.84$ - percent of cash purchases

$\phi = 0.1440$ - transaction fee (M2 data) by the inflation rate in the steady-state equilibrium. The level of inflation does effect the number of transactions, so it alters the consumption of the cash good and it alters the price level.

4 Inflation Risk

Now suppose that beginning in the next period there is a probability ρ of the money growth rate changing from its current steady-state level of ω to a new steady-state level of ω' which is selected from the distribution Ω. For simplicity of notation let us assume that Ω is countablely finite. This is not a strong assumption since we can approximate any continuous distribution up to an arbitrarily small degree of error. Let $\varphi_j \in \Omega, \quad j = 1, \ldots, N$ be the probability that $\omega' = \omega_j$. That is, given that the money growth rate changes, φ_j is the probability that the new steady-state rate of money growth is ω_j. The sum of probabilities is one, $\sum_{j=1}^{N} \varphi_j = 1$. There is a probability $1 - \rho$ of no change in the money growth rate.

We will generally focus on the case where ρ is small, and on the case in which the regime shift does not actually occur. We are interested in the effect of inflation risk in the steady-state equilibrium in which that risk has not yet been realized. It will simplify our analysis if we define the following:

$$\breve{p} \equiv \sum_{j=1}^{N} \varphi_j \cdot p_j . \tag{25}$$

$$\breve{\omega} \equiv \sum_{j=1}^{N} \varphi_j \cdot \omega_j \tag{26}$$

$$\Theta \equiv \sum_{j=1}^{N} \varphi_j \cdot \frac{\lambda_j}{\omega_j} \tag{27}$$

$$\eta \equiv \sum_{j=1}^{N} \varphi_j \cdot \frac{n_j \cdot \mu_j}{\omega_j} \tag{28}$$

$$\chi \equiv \sum_{j=1}^{N} \varphi_j \cdot \left(q_j + d_j\right) \cdot \lambda_j \tag{29}$$

$$\Lambda \equiv \sum_{j=1}^{N} \varphi_j \cdot f_K\left(K, L_j \mid \rho_j, \Omega_j\right) \cdot p_j \tag{30}$$

Equation 25 is the expected price level if there is a change in the money growth rate policy. Equation 26 is the expected money growth rate if there is a change in the money growth rate. Equation 27 is the expected marginal value of relaxing next period's budget constraint by taking additional real balances. Equation 28 is the expected marginal utility value of the liquidity services of money in the next period. Equation 29 is the expected utility value of a marginal increase in the equity share. Equation 30 is the expected value of the marginal product of capital in the future states if there is a policy regime change. Note that the marginal product of capital in future states may be a function of state-contingent future risk.

4.1 Defining Mean Preserving Risk

We consider six types of mean preserving inflation risk.

Type 1: $\breve{p} = p$. The expected price level does not deviate from its current steady-state level.

Type 2: $\Theta = \dfrac{\lambda}{\omega}$. The expected value of relaxing the budget constraint by one unit of currency is equal to the current utility value of relaxing the budget constraint by one unit of currency.

Type 3: $\eta = i \cdot \frac{\lambda}{\omega}$. The expected liquidity value of money is equal to the current marginal utility value of money in the budget constraint multiplied by the nominal interest rate.

Type 4: $\frac{\partial y}{\partial \rho} = \frac{\partial k}{\partial \rho} = \frac{\partial L}{\partial \rho} = 0$. The real, production-side, variables do not change with inflation risk.

Type 5: $q\lambda = \beta \cdot \chi$. The discounted utility value of next period's equity and dividend is equal to today's utility value of the economy's equity. Or, the expected equity return is equal to the risk-free stationary-state value.

Type 6: $\Lambda = p \cdot \left(\beta^{-1} - 1 + \delta\right)$. The expected value of MP_K, given a policy regime switch, is the same as the value in the risk-free equilibrium.

4.2 Risk and the Price Level

The number of transactions per period can be found by combining the consumer's first order condition for real balances, equation 17, with the cash-in-advance constraint, equation 12. We obtain a square root formula for the level of resources put into transacting:

$$\tau = \frac{\sqrt{B^2 + 4 \cdot \phi \cdot B \cdot \alpha(Y - I)} - B}{2 \cdot \phi} \tag{31}$$

where $B = \frac{\omega}{\beta}(1-\rho)^{-1} - 1 - \frac{\omega}{\lambda} \cdot \frac{\rho}{1-\rho}(\Theta + \eta)$. (32)

If $\rho = 0$ or if $\Theta + \eta = \frac{\lambda}{\beta}$ then $B = i$ and we obtain the risk-free solution for τ, and therefore for n and p. The first case is zero probability of regime change, the second is a mean preserving risk. A lack of risk or a mean preserving risk does not affect the price level, velocity of money or the level of real balances.

If the overall risk is toward a higher level of inflation, then $B > \frac{\omega}{\beta} - 1$. This leads to an increased in the values of τ, n, and p. That is, an increase in inflation risk leads consumers to reduce their real balances so there is a one-off increase in the price level. During the transition period, increasing inflation risk leads to an increase in the short run inflation. Similarly, if the risk is towards an overall lower level of inflation then the price level and velocity become smaller and the level of real balances increases.

4.3 Real Effects

Higher inflation, if it is realized, leads to a one-off increase in the price level in addition to the increased rate of future price growth. A physical asset, such as capital stock, will enjoy an increase in value from this increase in price level. Solving equation 4 for the current marginal utility of capital we obtain:

$$f_K(K, L \mid \omega) = (1-\rho)^{-1}\beta^{-1} - 1 + \delta - \frac{\rho}{1-\rho}\sum_{j=1}^{N}\left[\varphi_j \cdot \left[1 - \delta + f_K(K, L_j \mid \omega_j)\right] \cdot \frac{p_j}{p}\right] \qquad (33)$$

From equation 33 we can determine that higher expected inflation reduces the equilibrium marginal product of capital. Inflation risk increases capital investment.

4.4 Nominal Returns Under Risk

Under inflation risk, the consumer's optimal condition for holding bonds, equation 18, can be expressed as:

$$(1+i)^{-1}\lambda = \beta \cdot \left[(1-\rho) \cdot \frac{\lambda}{\omega} + \rho \cdot \sum_{j=1}^{N}\varphi_j \cdot \frac{\lambda_j}{\omega_j}\right]. \qquad (34)$$

Solving for the nominal interest rate we obtain:

$$i = \frac{\omega}{\beta}\left[1 - \rho + \rho \cdot \frac{\omega}{\lambda} \cdot \Theta\right]^{-1} - 1. \tag{35}$$

Notice that:

$$\frac{\partial i}{\partial \rho} = \frac{\omega}{\beta}\left(1 - \frac{\omega}{\lambda} \cdot \Theta\right)\left[1 - \rho + \rho \cdot \frac{\omega}{\lambda} \cdot \Theta\right]^{-2} \underset{<}{\overset{>}{=}} 0 \quad \mathit{iff} \quad \frac{\lambda}{\omega} \underset{<}{\overset{>}{=}} \Theta. \tag{36}$$

If the inflation risk is Type 2 mean preserving, then inflation risk has no effect on the nominal interest rate. That is, irrespective of the variance of the distribution of inflation risk, Ω, increases in inflation risk have no effect on interest rates if the risk does not change the utility value of real balances. Hence, when it comes to inflation risk, it is the first moment of the distribution that matters, not the second. If the distribution of inflation risk, Ω, causes the expected value of real balances to be smaller than its current value, $\Theta < \frac{\lambda}{\omega}$, then inflation risk increases the nominal interest rate. This occurs when, on balance, the expectation is toward higher future inflation.

The steady-state real interest rate is given by:

$$r = \frac{1}{\beta}\left[1 - \rho + \rho \cdot \frac{\omega}{\lambda} \cdot \Theta\right]^{-1} - 1. \tag{37}$$

A Type 2 mean preserving distribution of inflation risk does not alter the ex-post real return in the steady-state. As stated above, an overall risk of higher inflation increases the nominal interest rate. If this inflation risk is not realized, i.e. if there has been no actual change in the money growth rate policy, then the ex-post real interest rate increases in the inflation risk. This result is summarized in equation 38:

$$\frac{\partial r}{\partial \rho} = \frac{1}{\beta}\left(1 - \frac{\omega}{\lambda} \cdot \Theta\right)\left[1 - \rho + \rho \cdot \frac{\omega}{\lambda} \cdot \Theta\right]^{-2} \underset{<}{\overset{>}{=}} 0 \quad \mathit{iff} \quad \frac{\lambda}{\omega} \underset{<}{\overset{>}{=}} \Theta. \tag{38}$$

Thus, just as unexpected inflation causes a redistribution of resources from lenders to borrowers, inflation risk causes a redistribution from borrowers to lenders when that risk is unrealized.

The change in interest rates due to inflation risk can be interpreted as a risk premium. Note that the premium can be either positive or negative, depending upon the perceived distribution of the inflation risk. One contribution of this paper is the determination of risk premia endogenously within the model, rather than adding exogenously. It is our contention that adding a risk premium to a general equilibrium model without also adding a concomitant actual risk within the model violates the requirement of internal consistency which we have imposed upon the model.

5 Rational Expectations

The expected one period inflation is given by:

$$(1-\rho)\cdot\omega+\rho\cdot\frac{\breve{p}}{p}\cdot\breve{\omega} \tag{39}$$

If there is a policy regime change then the money growth rate is selected from the distribution Ω and there will be a one-off change in the price level. If the expectation is toward higher inflation, $\breve{p} > p$ and $\tilde{\omega} > \breve{\omega}$, then when the policy regime change is not realized, expected inflation will exceed the actual inflation rate, ω. This situation can exist for sustained periods of time. This may explain previous observations of apparent irrational behavior by consumers, Lewis (1989), Flood and Garber (1980), Salyer (1990). For instance forward prices, which incorporate the inflation risk, may deviate from the subsequent spot price which clears the market. The difference between these prices is not required to be of zero expectation or to be serially uncorrelated in order to be consistent with rational expectations.

6 News

In steady-state, the equilibrium values of both real and nominal variables depend upon the probability of policy regime change, ρ, and on the distribution of the resulting policy variable, Ω. The point of departure for this study is the rational expectations assumption, so we view ρ and Ω as the consumer's unbiased expectation of rare possible future events given available information.

Even in times when there is no actual change in policy regime, news may arrive to consumers about the likelihood of a future policy change or the distribution of that change. This news has real effects, price effects, and distributional effects.

There are copious examples of news apparently having strong immediate market effects. One example which stands out occurred in May-July 2002 when the Prime Minister of Turkey, Bülent Ecevit, entered the hospital with serious health concerns. The major Turkish stock market index declined immediately 3.77% , while Turkish Lira lost 2.7% of its value in one day, and was to lose a total of more than 20% over a period of less than two months.

Although no apparent real or monetary shock hit the economy as a result of this event, the Turkish stock market experienced a 5.4% decline in only one day and uncertainty continues to affect expectations the stock market declined a further 12.87% over 5 weeks, nominal interest rates jumped from 52.5 percent on 22 April 2002 to 69.6 percent on 17 June 2002. In the absence of any definable actual economic shocks, the economy's prices changed sharply due to news giving consumers information about future possibilities.

In this model, if the overal risk is toward higher inflation, $\theta > \frac{\lambda}{\omega}$, then an increase in the inflation risk, ρ, induces a short run increase in the price level and a reduction in the return to capital. Thus, inflation risk may explain the negative observed correlation between these variables, see Marshall (1992), Boudoukh, Richardson, and Whitelaw (1994), Love and Wen (1999). Similarly, we should see a negative correlation between the rate of return on nominal instruments and equities due to changes in the perceived level of inflation risk.

Two results of the model are unexpected. These are that the risk of higher inflation increases the equilibrium capital stock and output level, and that inflation risk affects the velocity of money, and therefore the level of real money balances.

6.1 Regime Change

Occasionally there will be a change in the money growth policy regime. If the change is to a higher money growth rate, then we should see a one-off increase in the price level due to the Cagan effect. *Ceteris Paribus,* holders of a nominal asset, money or bonds in this model, suffer a loss in the value of that asset. Holders of a real asset, equity, gain from the change. The resultant price levels and real variable changes depend not only on the realised change in policy, but on possible changes in the probability of future regime changes and the distribution of that change.

6.2 Measuring Risk

Since ρ and Ω are viewed as possibly changing each period, and since instances of actual policy regime change are viewed as rare, it is impossible for researchers to directly observe these parameters. However, it is possible to observe variables which are affected by this risk. When there has been no policy regime change, the ex-post real interest rate on bonds is a function of the risk parameters. Using equation 37, we can obtain:

$$\beta^{-1} \cdot (1+r)^{-1} = 1 - \rho + \rho \cdot \frac{\omega}{\lambda} \cdot \Theta \qquad (40)$$

The left hand side of equation 40 is, ex-post, observable, while the right hand side is essentially a measure of the risk premium on nominal bonds. Equation 39 is a sufficient statistic for the effect of inflation risk on nominal interest rates. Our proposed method is to use the inflation rate data to identify points of structural break in the series which signal policy regime change, and then use time series data on ex-post real interest rates to capture the risk premium.

7 Conclusion

We introduce a general equilibrium time dynamic economic model which displays monetary superneutrality, with respect to production variables and real rates of return. Inflation risk, however, does have real and distributional effects as well as price effects.
The risk considered here is a rare change of monetary growth policy regime. This view of risk can explain an observed systematic departure of expected inflation from subsequent observed inflation.

Each period the level and degree of inflation risk may change. This highlights the role of news as a driving factor in the economy. A perceived change in inflation risk has real, price and distributional effects, even in the absence of any actual real or monetary shocks. An increase in inflation risk causes in increase in the current price level and velocity of money. We also expect equity returns to fall and nominal returns to increase. This may explain previously reported correlations between these variables. Also, increasing inflation risk causes an increase in short term inflation.

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