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Money Demand and Relative Prices During Episodes of Hyperinflation

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ABSTRACT

We investigate the relationship between relative price changes and money demand behavior during hyperinflations, viewing relative price changes as real disturbances. We develop a general equilibrium model that relates the real and monetary sectors of the economy and that considers consumption and capital goods as heterogeneous. The model generates testable implications suggesting that monetary shocks may produce real effects, mainly through the relative price channel.

We use the model implications to design long-run restrictions to identify a structural vector autoregression, consisting of three fundamental disturbances (monetary, transaction frequency, and real). Our data sample includes two hyperinflationary episodes, post-World War I Germany (1920-23) and post-World War II China (1946-49). The empirical results support the contention that both real and nominal shocks have important effects on money demand and relative prices during hyperinflationary periods. Thus, conventional welfare loss measures of inflation using the traditional Cagan money demand specification may underestimate the true cost of hyperinflation.

Money Demand and Relative Prices During Episodes of Hyperinflation

I Introduction

Hyperinflations provide a fertile area for research topics because there remain so many unanswered questions surrounding these phenomena. Past research has been unable to examine completely some fundamental issues, such as whether economic fluctuations during hyperinflations are similar, whether money growth produces real effects, or whether real shocks have a significant impact on money demand beyond inflation expectations.

Cagan (1956), in his pivotal work, models money demand in an adaptive expectations framework, in which an increase in the expected rate of inflation raises the cost of holding money and thus reduces real balances.[1] In a recent article, Taylor (1991) employs cointegration techniques to reexamine the Cagan hyperinflation study and finds that the traditional money demand specification is not supported by the German data.[2] We infer that these results imply that variables in addition to expected inflation have significant impact on money demand.

We hypothesize that real activities have an important bearing on the behavior of money demand even in a hyperinflationary environment. In previous studies of hyperinflation, real variables have generally been excluded from the estimated money demand regression because of the absence of adequate output measures at a monthly frequency. In contrast to previous

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[1]Sargent (1977) modifies Cagan's approach by allowing individuals' expectations to be rational, while Frenkel (1977) implements the analysis using forward premium as a proxy for expected inflation. Abel, Dornbusch, Huizinga, and Marcus (1979) find that forward premium has significant explanatory power for money demand in addition to inflation expectations.

[2]Taylor shows that for the Cagan model to hold, real money demand and expected inflation must be cointegrated. For certain data samples, most notably for the post-World War I German hyperinflation (1920-1923), the null hypothesis of non-cointegration cannot be rejected for these series.

work, this paper develops a dynamic general equilibrium model that enables us to study the dynamic interactions between the real and the monetary sectors in a hyperinflationary environment.[3] We introduce money into a competitive firm-consumer model via a modified cash-in-advance constraint in which money velocity is allowed to vary, capturing a stylized feature of hyperinflations. Utilizing a simple capital storage technology, we consider consumption and capital goods as heterogeneous, thereby generating a well-defined relative price ratio (measured by the capital good price in units of consumption good). We impose asymmetric liquidity constraints on the purchase of the consumption versus the capital good, consistent with the real world observation. Disproportionate (consumption and capital good) price movements, therefore, create a plausible channel through which we can study the dynamic interactions between real and nominal variables.

Our main model implications suggest that money growth shocks decrease the demand for real money balances, but also increase the relative price of capital, a real effect. Real (Harrod-neutral) productivity shocks increase the output of consumption per unit of capital input, lowering the price of consumption relative to capital and raising the relative price of capital. When the productivity shock is multiplicative, its effect on real money demand is positive to the same degree as for the relative price.

The theoretical predictions allow us to impose necessary long-run restrictions to identify a structural vector autoregressive model in a fashion similar to Blanchard and Quah (1989), King, Plosser, Stock, and Watson (1991), and Ahmed, Ickes, Wang, and Yoo (forthcoming). We do not impose a structure on the short-run interactions that may be controversial, especially

[3]Policano and Choi (1978) examine relative price effects on money demand in a static, partial equilibrium model. In contrast, we allow relative prices and the inflation rate to be determined endogenously in a dynamic, general equilibrium framework.

in a chaotic hyperinflationary environment. Rather our approach allows the data to determine the short-run dynamics, while using the theoretical model to provide a structural interpretation of the fundamental disturbances driving the economy we analyze.

Based on data availability, we investigate hyperinflation in the cases of post-World War I Germany (1920:1-1923:7) and post-World War II China (1946:1-1949:3). We estimate a system consisting of three variables (money growth, the money demand-relative price ratio, and the relative price) and three fundamental orthogonal disturbances (money growth, transactions interval or negative velocity, and real or productivity shocks). We use impulse response functions to display the short-run reaction of each variable to each unit shock and perform variance decompositions to quantitatively assess the important sources of fluctuations in money demand and relative price.

Our results support the general conclusion that there are significant effects of both real and nominal shocks on money demand and relative prices in hyperinflations. There are some differences across the two samples: for the German data, about one third of the variance in money demand changes is associated with real variables, whereas for the Chinese data real variables appear related to two thirds of the variance in money demand changes.[4] Despite the contrasting results, the evidence implies that there is a significant role for real variables in the analysis of money demand in hyperinflations. The typical measures of welfare loss from inflation that use the Cagan money demand specification will overlook the impact of real distortions from nominal disturbances and thus underestimate their true cost.

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[4] The contrasting results are consistent with institutional facts that offer explanations for the distinct results.

The remainder of the paper is as follows. Section II presents some historical background of the German and Chinese hyperinflationary experiences. The following section develops the model and derives the implications. Section IV describes the empirical methodology and the data and also discusses the estimations and results. Section V offers conclusions.

II Historical Retrospective

We study two hyperinflationary episodes, post-World War I Germany and post-World War II China, both of which experienced the highest inflation with the longest sample and richest reliable data. Most previous work on hyperinflations assumed that all prices increased equi-proportionately. In contrast, we examine the relative price movements measured by the ratio of the wholesale price to the cost-of-living index.[5] These two countries are the only ones experiencing hyperinflation, to our knowledge, to have separate indexes for consumer and wholesale prices. The two price index measures moved differently during these hyperinflations. In Germany, the relative price ratio increased from 1.17 in April 1920 to 1.94 in November 1922 and then declined to 1.49 in July 1923. Similarly, the relative price ratio in China rose from 0.94 in March 1946 to 2.0 in December 1948 and then dropped to 1.64 in March 1949.

A. The German Case

The hyperinflationary experience of Germany from 1920 to 1923 followed the accumulation of World War I debt and the assignment of war reparations in the Treaty of

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[5] Garber (1982) first used this measure as a proxy for the relative price of capital to consumption goods because of the absence of a capital goods price index. As Garber noted, the proxy measure understates the actual relative price movement of capital goods because the wholesale price index contains prices for some final goods in addition to primary inputs and capital goods.

Versailles, a significant financial burden atop a war-battered economy.[6] The fiscal authority in Germany had insufficient means to raise the necessary funds for its expenditures, and the monetary authority (Reichsbank), actively discounted the debt of the fiscal authority throughout the hyperinflationary period. The accelerating growth in both the government deficit and the money supply laid the necessary groundwork for accelerating hyperinflation. There were several unsuccessful attempts at price stabilization, and the rates of inflation experienced throughout the hyperinflation were not monotonic, often fluctuating dramatically. Despite a number of failed reforms, the fiscal/monetary reform in November 1923 finally proved credible and succeeded.

The extreme behavior of nominal measures over the period from April 1920 to July 1923 emphasizes the degree of chaos during the hyperinflation. The price level, measured by a cost-of-living index, increased by a factor of 3750, while inflation averaged 21 percent per month. The hyperinflation, however, exploded from a moderate average rate of 6 percent per month in the period up to June 1922 to an average rate of 52 percent over the remainder. The nominal money supply grew at an average rate of 16 percent per month, increasing by a factor of 560. The foreign exchange rate, indicating the international value of the German mark during the hyperinflation, depreciated at an accelerating rate that averaged 21 percent per month. The domestic value of real balances at the end of the period was .15 of its initial value, whereas the international value fell to .09.

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[6] The actual reparations payment schedule, referred to as the London Schedule, was issued (as an ultimatum) in January 1921.

B. The Chinese Case

Following World War II, the Nationalist government faced extreme budget shortfalls due to tremendous military expenditure from the Sino-Japanese War and the post-war reconstruction. Severe conflict between Chinese Nationalists and Chinese Communists fueled widespread political instability. The Chinese Civil War ensued throughout this period. These fiscal and political difficulties forced China to experience a continuous inflation for the period from 1946 to 1949. In the midst of the hyperinflation, the Communists issued forty local currencies to rival the official currency, the Chinese Nationalist Currency (CNC). In August 1948, the CNC was replaced by the Chinese gold yuan (i.e., gold note) in an unsuccessful attempt at currency reform by the Nationalist Government. The monetary authority failed to provide credibility to the reform attempt because it continued to monetize growing government deficits until the collapse of the monetary regime in May 1949.

The Chinese hyperinflation was the second most explosive one ever recorded; only the post-World War II Hungarian inflation was more rapid, although it was much shorter. The price level (measured by a cost-of-living index) skyrocketed by a factor of 2.6 million between March 1946 and March 1949. The inflation rate averaged 41 percent per month for the entire sample period; however, the rate accelerated from a 26 percent per month average before the 1948 reform to an average of 106 percent per month afterward. A rapid rise in the money supply provided a major force driving the hyperinflation: the money supply increased by a factor of .25 million and grew at an accelerating rate from an average of 22 to 86 percent per month before and after the 1948 reform. On the international currency market, the exchange value of the CNC/gold yuan depreciated dramatically by a factor of 24 million. Consequently, while the domestic value of real balances fell to one-tenth its original value, its international value dropped to .01.

C. Comparison

The political conditions within war-beleaguered Germany were in transition toward reconstruction. In contrast, China, though recovering from the Sino-Japanese War, faced a widespread civil war with increasing political instabilities. The domestic and international real values of the Chinese currency differed by a factor of ten, illustrating the lack of confidence in the regime by foreigners.

In each country domestic money no longer served as a unit of account or store of value. However, the Chinese monies still maintained the transactions role as media of exchange even in the most severe hyperinflationary periods. Money retained its role because there were strictly enforced regulations on the use of official currencies and Chinese are culturally law-abiding.[7] The lack of effective price controls in China also enhanced the use of money in transactions.[8] In contrast, Germany enforced extensive price controls that made barter more effective.[9] The enforced use of official money for transactions in China together with pessimistic expectations of any positive solution to the civil war made the velocity of money increase sharply.[10] It is

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[7] Campbell and Tullock (1954), p. 244.

[8] ibid., p. 244.

[9] Webb (1989) notes that in Germany certain public utility prices and rents were subject to price controls, so that the cost-of-living index did not adjust fully to inflationary increases. The wholesale price index averaged prices of imports and domestic production of mostly intermediate products and were freer to move with market forces.

[10] The sharp increase in velocity is noted by Huang (1948), p. 572.

notable that the German fiscal/monetary reform was effective for stopping the hyperinflation. On the other hand, the Chinese central bank collapsed, and the data following the Communist takeover is relatively unavailable, so we cannot determine its end.

III The Model

The theoretical framework attempts to go one step further than the Cagan money demand model by studying a general equilibrium dynamic optimization problem for consumption, capital accumulation, and real money holdings.

For convenience, we introduce money into the model economy using a generalized cash-in-advance (CIA) constraint. In contrast to the conventional Lucas (1980) model, we allow velocity to vary in order to capture a major feature of hyperinflations. In contrast to Stockman (1981), we assume that capital goods purchases are free of the liquidity constraint, which better approximates transactions in the actual economy.[11] Let M and P represent the (beginning-of-period) nominal money stock and the price level (in units of consumption goods), respectively. Let $m_t = M_t/P_t$ denote (beginning-of-period) real money balances, and v refer to autonomous movements in velocity. Changes in v may be thought of as resulting from alterations in inflation expectations, transactions costs, and degree of economic uncertainty. More specifically, v is used to capture that component of velocity <u>not</u> directly caused by monetary expansion.[12] We summarize the linkage between real and nominal activities by expressing the nonstorable final consumption good, c, as $c_t = v_t\, m_t$.

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[11] If a fraction of capital goods is subject to a CIA constraint, the main results will still hold.

[12] The empirical identification specified in (13) is consistent with this concept of velocity shock.

The consumption good is produced using an intermediate capital good, x, owned by individual consumers. Let y denote the representative firm's final good production and q represent the relative price of the capital to consumption good. Therefore, the firm's maximization problem is:

$$Max_{x_t} \quad \phi_t \quad = \quad y_t \; - \; q_t \, x_t \quad = \quad a_t \, x_t^{\alpha} \; - \; q_t \, x_t, \tag{1}$$

where a is a positive Harrod-neutral technological factor and (1-α) measures the degree of diminishing returns of the production technology. The first-order condition implies :

$$q_t = \alpha \; a_t \, x_t^{\alpha-1}. \tag{2}$$

Without loss of generality, we assume that the consumer-supplied intermediate capital good is produced through a simple storage technology analogous to McCallum (1983). Let z denote the (beginning-of-period) capital stock. We specify the storage technology as:

$$z_{t+1} = \gamma \; (z_t \, - \, x_t), \tag{3}$$

where $\gamma > 0$ is the (net-of-depreciation) growth factor.[13]

Define the inflation rate from period t to t+1 as π_{t+1} [= (P_{t+1}/P_t) - 1]. Real balances at the end of period t, M_{t+1}/P_t, can be expressed as $(1+\pi_{t+1})m_{t+1}$. Given the redistribution of the firm's profit, ϕ, and the lump-sum real money transfer from the government, τ, the representative consumer faces the following budget constraint:[14]

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[13] For simplification, we only focus on cases in which the non-negativity constraint on z, $z_t \geq 0 \; \forall$ t, is not binding.

[14] We have applied $c_t = v_t \, m_t$ to the derivation of the following equation.

$$(1 + \pi_{t+1})\, m_{t+1} = q_t\, x_t + \phi_t - m_t\, (v_t - 1) + \tau_t. \tag{4}$$

We assume that the consumer's utility is time-additive with a constant discount factor β and with a stationary, logarithmic instantaneous utility function. The consumer's optimization problem is then:

$$Max_{x_t,\, z_{t+1},\, m_{t+1}} \; E_0 \sum_{t=0}^{\infty} \beta^t \ln c_t = E_0 \sum_{t=0}^{\infty} \beta^t \ln(v_t\, m_t), \tag{5}$$

subject to (3) and (4).

Let $\lambda_{1,t}$ and $\lambda_{2,t}$ be the Lagrange multipliers associated with (3) and (4), respectively. The first-order conditions of the consumer's problem are:

$$-\gamma \lambda_{1,t} + \lambda_{2,t}\, q_t = 0. \tag{6}$$

$$-\lambda_{1t} + \gamma \lambda_{1,t+1} = 0. \tag{7}$$

$$E_{t-1} \frac{1}{m_{t+1}} \{ \beta^{t+1} - m_{t+1} [(1 + \pi_{t+1}) \lambda_{2,t} + (v_{t+1} - 1) \lambda_{2,t+1}] \} = 0. \tag{8}$$

Notably, equation (8) ensures intertemporal consumption efficiency and no arbitrage opportunities between the two assets, capital and money, neither intertemporally nor contemporaneously.

To close the model, we specify the government's money supply process as: $\tau_t = \mu_{t+1} m_t$. Under money market equilibrium, it is useful to note that: $m_{t+1}/m_t = (1+\mu_{t+1})/(1+\pi_{t+1})$. The goods market clearing condition ensures that $c_t = y_t$.

By characterizing the steady-state equilibrium, the model predicts that an increase in the money growth rate will increase the relative price of the capital good.[15] Intuitively, higher money growth will reduce real balances and thus limit the demand for the cash-constrained consumption good. Moreover, the demand for the capital good, which serves as a store of value, increases. As a consequence, the relative price ratio of the capital to consumption good increases. Further, the resulting decline in real balances combined with the increase in the relative price leads to a lower money demand to relative price ratio.

An increase in velocity (that shortens the transactions interval) has two opposite effects on the relative price. On the one hand, it reduces the cash requirement for consumption purchases accommodating increases in the demand for the consumption good, and hence the relative price ratio declines. On the other hand, when velocity increases the store-of-value role for capital decreases. Then, the resulting decumulation of capital increases the return to capital under diminishing returns, and thus, the relative price increases. On net, we are unable to determine which effect dominates. However, as velocity increases, real money balances decrease directly, dominating the relative price changes (even if it is negative) and thereby leading to a net negative effect on the real balances to relative price ratio.

Finally, any multiplicative Harrod-neutral technological disturbance will not affect the money demand-relative price ratio.[16] On the other hand, a technological improvement increases

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[15]In the Appendix A, we derive the model implications that provide support for the intuitive descriptions in the text. Rather than explore the technical aspects of the model we concentrate on highlighting the testable implications in the discussion.

[16]This can be seen clearly in the first equality in equation (A3) in the Appendix A because a does not appear.

the supply of final consumption goods given the same level of capital good input, thus lowering the price of the consumption good and raising the relative price ratio.

IV Empirical Analysis

The theoretical model derived in section III provides implications on the long-run relationships between the variables of interest and the fundamental disturbances, specifically money growth, transactions interval (inverse of velocity), and real (productivity) shocks.[17] For convenience, we refer to these three shocks as SM, ST, and SP, respectively. Applying the structural vector autoregression (VAR) method developed by Blanchard and Quah (1989), King, et al. (1991), and Ahmed et al. (forthcoming), we utilize these long-run relationships to identify the system and interpret the shocks.[18] By imposing only long-run restrictions based upon the theoretical model, we are able to retrieve the structural disturbances while allowing the data to determine the short-run dynamics.

The identification method employs a long-run causal ordering of the variables in the estimated system that, in our case, involves two primary assumptions. First, we take the money growth process as predetermined in the long-run to individual firms and consumers. Second, we have shown that a multiplicative Harrod-neutral productivity shock does not affect the ratio of money demand to the relative price of the capital good. Therefore, in the structural VAR system below, we impose the long-run ordering starting with the money growth rate, followed

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[17]In a hyperinflation, we believe that the monetary and fiscal authorities are not independent. Thus, we refer to the money growth shock as a combined fiscal and monetary shock.

[18]We emphasize that the order of the system is based on implications from a theoretical model in contrast to Sims (1980) and in our case only impacts in the long run. Unlike Bernanke (1986), we provide a direct interpretation of the structural shocks.

by the money demand-relative price ratio, and then the relative price ratio, in conjunction with the shocks specified above.[19]

A. Empirical Methodology

Proponents of identification via long-run restrictions offer it as an alternative to methods that impose restrictions on the short-run dynamics. Economists generally feel more confident in their knowledge of long-run relationships than their understanding of short-run interactions, so that constraints on the long-run responses appear less objectionable and more economically justifiable.

Let ξ_t represent the (3x1) vector of structural disturbances (SM, ST, SP), X_t represent the (3x1) vector of variables (money growth, money demand-relative price ratio, relative price ratio) in stationary form, and C(L) represent a non-singular matrix of moving average coefficients, where L is the lag operator. The structural model is then:

$$X_t = C(L)\,\xi_t,\quad Var(\xi_t) = \Sigma. \tag{9}$$

The variance-covariance matrix (Σ) is diagonal, provided all fundamental shocks are orthogonal. By the long-run causal ordering, the long-run moving average matrix, C(1), is lower triangular. Then, the structural model can be rewritten

$$A(L)\,DX_t = B\,X_{t-1} + \xi_t. \tag{10}$$

where the first-difference of A(L) is $C^{-1}(L)-C^{-1}(1)L$, B is $-C^{-1}(1)$, and D denotes difference operator.

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[19]The identification of a system must impose restrictions. We believe that our assumptions are reasonable and allow the data to be more informative regarding the short-run interactions among the variables we focus on.

The estimated reduced form of the system is:

$$F(L)\, DX_t = G\, X_{t-1} + u_t, \quad Var(u_t) = \Omega. \tag{11}$$

where u_t are the reduced form errors. To link the reduced form to the structural form, we transform the above equation as:

$$HG^{-1}\, F(L)\, DX_t = HX_{t-1} + HG^{-1}\, u_t, \tag{12}$$

where H is the inverse of the Cholesky factor of $[G^{-1}\, \hat{\Omega}\, (G^{-1})']$, and by construction $Var[HG^{-1}u_t] = \Sigma$. By comparing the reduced form with the structural form, the estimated long-run moving average matrix is then $-H^{-1}$. Because we have normalized the sign of the diagonal elements of the C(1) matrix by theory, the Cholesky factor is unique and, therefore, the structural shocks retrieved by this method are unique.

B. The Data

We employ two hyperinflation data sets: Germany from January 1920 to July 1923 and China from January 1946 to March 1949. The German data are taken from Holtfrerich (1986), which is based upon Statistiches Reichsampt. For China, we employ data translated from The Shanghai Price Index Collection before and after the Civil War (in Chinese).

In each country, a wholesale price index (WPI) measures prices for capital goods, whereas a cost-of-living index (CLI) measures prices for consumption goods. We take 1913/14=1.00 as the base year for the German price indexes, and for China the base year is 1937=1.00. We then compute the ratio of the wholesale to the cost-of-living index as the relative price measure. The price level is measured by the cost-of-living index.

The money supply measure (MS) for Germany is the monetary base, whereas for China we use official currencies and notes.[20] Both money stock variables are measured mid-month using a simple (geometric) moving average. The German money supply is in billions of marks, while the Chinese money supply is in billions of CNCs.[21] Money demand (MD) is therefore defined as the nominal money stock deflated by the cost-of-living index.

To implement the empirical study, we transform the raw data to obtain the following series:

MGR = Money supply growth rate, Dln(MS);

MRP = Money demand - relative price ratio, ln(MD)-ln(WPI/CLI);

RP = Relative price, ln(WPI/CLI).

We define the variable MRP as the ratio of money demand to relative price in order to identify the model using long-run restrictions. In the estimation, we employ first differences of the three transformed variables and denote them by DMGR, DMRP, and DRP, respectively. We summarize the univariate statistics for both countries in Tables 1A and 1B.[22]

In summary, apart from the lag dynamics, the structural VAR system in its moving average form can be written as:

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[20] Holtfrerich (1986) notes that the monetary base best captures the money supply measure because the reserves held in the Reichsbank were a substantial proportion of the total stock. Such a figure is unavailable in China, but banking reserves in China were less essential to the monetary system.

[21] We make an adjustment to the money supply data for the revaluation of the Chinese currency, the failed monetary reform, in September 1948 to keep the series consistent.

[22] In Appendix B, we present graphical display of the data series. We present a plot of the inflation rate, INF, followed by plots of money growth, MGR, real money demand-relative price ratio, MRP, and the relative price, RP, for Germany (Figure B1) and China (Figure B2).

$$\begin{bmatrix} DMGR \\ DMRP \\ DRP \end{bmatrix} = \begin{bmatrix} \mu_0 \\ m_0 \\ a_0 \end{bmatrix} + \begin{bmatrix} c_{11} & 0 & 0 \\ c_{21} & c_{22} & 0 \\ c_{31} & c_{32} & c_{33} \end{bmatrix} \begin{bmatrix} SM \\ ST \\ SP \end{bmatrix} \tag{13}$$

where μ_0, m_0, and q_0 capture constant drifts for the levels of the three transformed variables. We have explained the justification for the lower triangular structure of C(1) in the beginning of section IV, based on the long-run monetary growth model. The fundamental disturbances are constructed such that all diagonal elements of C(1) are positive. For example, the ST shock represents a negative autonomous movement in money velocity, thus normalizing c_{22} to be positive. Moreover, the theoretical results imply the following signs for the (non-zero) off-diagonal elements. Higher money growth implies a decrease in the money demand-relative price ratio and an increase in the relative price ratio, so that $c_{21} < 0$ and $c_{31} > 0$. A positive transactions interval shock (a negative velocity shock) involves two counteracting effects on the relative price, so the model does not offer an unambiguous implication. Thus, we cannot offer an unambiguous prediction for the sign of c_{32}.

C. Empirical Results

Our analysis deviates from traditional investigations of money demand in hyperinflation that rely on partial equilibrium frameworks. Prior studies, most notably Cagan (1956), Frenkel (1977), and Abel et al. (1979), focus on data measures of expected inflation without addressing the role of any real macroeconomic aggregate. This is not surprising given that their theoretical paradigm concentrates only on expectations of aggregate price changes and that real measures are usually unavailable at high enough frequency for estimation. Our empirical method, however, allows us to identify both nominal and real disturbances. Therefore, we can quantitatively assess the important sources of money demand fluctuations and the dynamic interactions between the real and the nominal variables.

In recent time-series empirical work, researchers often address the issue of data stationarity by employing various statistical tests indicating integration, cointegration, or non-integration of the time series. These statistical tests often require numerous data points in order to generate test statistics with the desired properties. In our empirical work, we perform some analysis of the stationarity properties of the data indicating that the relevant series are integrated of order one.[23] However, we will not emphasize these statistics because our sample of less than forty observations is insufficient for the test procedures.

Using the cointegration test established in Engle and Granger (1987) and the critical values reported in Engle and Yoo (1987), we find no evidence of cointegration among the variables, money supply growth, money demand-relative price ratio, and relative price.[24] Therefore, the variables can be estimated by the VAR method described above because the moving-average coefficient matrix is non-singular. Since all the structural shocks are fundamental, the covariance matrix is diagonal when the long-run restrictions are imposed. The evidence of no cointegration implies that there are three stochastic trends in the VAR system; also, the shocks that drive the system in the long-run dynamics are the same as those propagating the short-run dynamics. Our estimation procedure allows the data to determine short-run dynamics and identifies the model using weaker economic assumptions than alternative methods.

The Akaike information criterion suggests that the lag length for the VAR is two and three, respectively, for Germany and China. The estimated long-run responses conform with

[23] Results are available on request.

[24] Results are available on request.

the theoretical predictions. For Germany, the estimated long-run responses of first differences of money growth, money demand-relative price ratio, and relative price to a unit shock in money supply growth are .84, -2.4, and .22, respectively. Similarly, the estimated long-run responses for the Chinese case are .22, -.21, and -.07, respectively. In response to the transactions interval (negative velocity) shock, the money demand-relative price ratio and the relative price reflect a permanent change of .31 and -.24, respectively, in Germany's case, while the corresponding estimates for China are .113 and -.02. Finally, a unit shock in productivity results in an increase of .79 and .72 in the relative price ratios for Germany and China, respectively.

Since our main interest concerning the hyperinflationary phenomena is in the short-run dynamics, the above long-run responses are used only to check the consistency of the estimation with the theory. The remainder of the text will focus on the impulse response functions (IRFs) and the variance decompositions (VDCs) of money demand and the relative price. The IRFs show the estimated response of each variable to a one-standard-deviation impulse in the fundamental shock, while the VDCs account for the percentage of the forecast error variance of each variable explained by the particular shock.[25]

The German Case

We plot the impulse responses for Germany in Figure 1A. Concentrating on the reactions of money demand to shocks, which are displayed in the top two panels of the figure,

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[25] In Appendix C, we present results from an alternative specification and a different identification technique. The results suggest that our main conclusion is robust to these alternatives.

we find that the money growth shock reduces money demand significantly in the short-run.[26] The effect on the level is hump-shaped, but persistently negative; specifically, money demand's reaction reaches a trough in the third month after the shock and then retraces to a smaller negative number. Money demand appears to have no significant reaction to the transactions interval shock until the fourth month after the disturbance. The cumulative reaction to the shock is positive but small, remaining so throughout the rest of the forecast horizon. The productivity shock has a significant impact on money demand for the first two periods after the shock, and the level response is hump-shaped and also persistent.

In Table 2A, we present the results of the variance decompositions for selected forecast horizons (1, 2, 3, 6, 12, and 24 months). On impact, the money growth shock accounts for about one-third of the forecast variance of the rate of change of money demand and the productivity shock accounts for approximately the other two-thirds. After the first month, the effect of the productivity shock diminishes to less than one-third while the money growth shock becomes more influential. Interestingly, throughout the entire forecast horizon, the transactions interval shock explains only an insignificant fraction of the forecast variance of money demand changes.

We next examine the impulse responses of the relative price variable. Consistent with our model implication, shocks to money growth increase significantly the relative price ratio, although the cumulative response appears short-lived. Changes in the transactions interval lead to a significant negative impact effect on the relative price. Finally, the productivity shock

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[26] We compute simulated standard errors using 1,000 replications of the system. Following Shapiro and Watson (1988), we employ one-standard-error bands in the impulse responses to imply significance.

significantly affects the relative price ratio on impact, an effect that appears persistent from the cumulative impulse response graph.

More than 40 percent of the forecast error variance of the rate of change in the relative price ratio are explained by the money growth shock. The transactions interval shock accounts for 47 percent of the variance of the rate of change in the relative price ratio in the first month, declining to 35 percent at the 24-month horizon. About 15 percent of the relative price forecast error variance is explained by the productivity shock.

The Chinese Case

The impulse responses for China are presented in Figure 1B. The negative effect of money growth shocks on money demand is only marginally significant in the first month. Two months after the transactions interval disturbance, money demand displays a significant increase in response. The cumulative effect of the impulse is positive and appears persistent throughout the remaining forecast horizon. Money demand displays a significantly positive response on impact to the productivity shock, but such an effect appears to diminish over time.

The variance decompositions for China are displayed in Table 2B. Except for the first month forecast horizon where the rate of change of money demand depends mostly on the money growth shock, both money growth and transactions interval shocks explain about 40 percent of the forecast error variance of money demand. On the other hand, the productivity shock accounts for approximately 20 percent of that variance.

The relative price reaction to money growth shocks is positive but not very significant. In response to the transactions interval shock, the relative price ratio declines only for the short-run horizon. However, the productivity shock appears to play a very important role in driving the relative price. The level response achieves a peak five months out, and the cumulative effect is fairly persistent.

Money growth explains only about 20 percent of the forecast error variance of the rate of change in the relative price ratio. Although the influence of the transactions interval shock increases and that of the productivity shock diminishes over the forecast horizon, each shock accounts for approximately 40 percent of the relative price variance.

Discussion

Comparing the results from the two countries, we find that in both countries the transactions interval shock accounts for about 40 percent of the forecast error variance of the relative price ratio. However, the money growth shock has a larger impact, compared to the productivity shock, on relative prices in Germany than in China. We can interpret the latter finding as resulting from the effectiveness of price controls on certain German final goods prices versus the lack of enforced price ceilings in China. German price controls made consumption goods prices adjust only partially to money supply shocks relative to wholesale prices that move more freely to market forces. As a result, money growth disturbances are more influential in relative price responses in contrast to China, in which the productivity shock is the main driving force.

As mentioned above, the Chinese official monies retained their role as media of exchange despite the hyperinflation. The consequent absence of barter transactions together with continued pessimistic expectations and increased economic uncertainties raised money velocity and shortened the transactions interval. Therefore, the transactions interval shock is expected to be more important for interpretations of Chinese money demand behavior than in the German case. Nonetheless, there is a limit to feasible transaction frequency, and thus real balances in China will react less to the money growth shock in comparison to Germany.

V Concluding Remarks

Our study of two hyperinflationary instances emphasizes that shocks to nominal variables (e.g., money growth) can have important effects on real measures (relative prices) in such episodes. Also, we show that real (productivity) shocks may affect the dynamic behavior of money demand variables in hyperinflations. Both issues have not been addressed in prior research, mainly due to the lack of real aggregate measures at a monthly frequency. However, we are able to employ data, suggested by a theoretical model, that allow us to investigate issues, like, for example, whether hyperinflationary money demand shifts as a result of real shocks.

Our general equilibrium theoretical model generates results that provide an explicit framework for the empirical work. The model implications lead us to a structural empirical model using long-run restrictions to identify the sources of shocks to the system. Thus, we can give direct interpretations to the impulse responses and variance decompositions from the estimated structural VAR. We find empirical evidence suggesting that real (productivity) shocks can affect money demand significantly, as well as that nominal shocks affect real variables. Contrasting results from the two countries emphasize that there can be important differences in the behavior of relative prices and money demand in hyperinflationary episodes. We note that these differences in results are consistent with institutional differences found in descriptions of each hyperinflationary period.

In summary, both theory and estimation suggest that dynamic interactions between nominal and real variables are significant in hyperinflationary periods. We believe that both nominal and real shocks are relevant for understanding the fluctuations of macroeconomic aggregates in these episodes. Also, our results relate to the typical welfare analysis of inflation. Conventional studies measure the welfare loss from inflation in terms of the Harberger triangle of money demand specified as a stable function of expected inflation. The application of this partial equilibrium method overlooks the welfare loss from real distortions from relative price fluctuations arising from nominal disturbances, thus underestimating the true cost of hyperinflation.

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Table 1A: Descriptive Statistics

German Hyperinflation: January 1920 to July 1923

Variable	Mean	Variance	Standard Error of the Mean
π (per month)	.21	.131	.057
1/20 to 6/22	.06	.005	.013
7/22 to 7/23	.52	.165	.111
m/q (ln)	1.17	.690	.131
1/20 to 6/22	1.69	.109	.064
7/22 to 7/23	.10	.162	.111
q (ln)	.234	.058	.038
1/20 to 6/22	.109	.027	.032
7/22 to 7/23	.492	.020	.039
μ (per month)	.16	.043	.033
1/20 to 6/22	.04	.002	.009
7/22 to 7/23	.41	.034	.051

Table 1B: Descriptive Statistics

Chinese Hyperinflation: January 1946 to March 1949

Variable	Mean	Variance	Standard Error of the Mean
π (per month)	.41	.278	.087
1/46 to 8/48	.26	.063	.046
9/48 to 3/49	1.06	.754	.328
m/q (ln)	-5.79	.555	.122
1/46 to 8/48	-5.59	.186	.079
9/48 to 3/49	-6.65	1.36	.440
q (ln)	.108	.059	.039
1/46 to 8/48	.036	.030	.032
9/48 to 3/49	.417	.069	.099
μ (per month)	.34	.103	.053
1/46 to 8/48	.22	.034	.034
9/48 to 3/49	.86	.058	.091

Table 2A: Structural VAR Variance Decompositions
German Hyperinflation: January 1920 to July 1923

Periods Out	Percent of Variance in Rate of Change in Relative Price Due to Shocks in: Money Supply Growth	Transactions Interval	Productivity
1	40.45	47.16	12.38
	(24.4)	(21.2)	(16.1)
2	42.87	41.38	15.75
	(17.6)	(17.8)	(12.5)
3	46.77	37.76	15.46
	(15.6)	(15.6)	(11.6)
6	48.33	35.87	15.80
	(14.7)	(14.3)	(10.8)
12	49.39	34.76	15.85
	(15.1)	(14.7)	(11.0)
24	49.60	34.55	15.84
	(16.2)	(15.7)	(11.5)

Periods Out	Percent of Variance in Rate of Change in Money Demand Due to Shocks in: Money Supply Growth	Transactions Interval	Productivity
1	34.06	.15	65.79
	(19.7)	(7.9)	(21.3)
2	67.12	.08	32.80
	(15.1)	(7.28)	(13.7)
3	66.55	.34	33.10
	(15.4)	(7.1)	(14.1)
6	66.03	6.88	27.09
	(15.8)	(8.3)	(12.3)
12	66.45	6.63	26.92
	(16.0)	(8.7)	(12.5)
24	66.49	6.65	26.86
	(16.2)	(10.0)	(12.6)

Simulated standard errors from 1,000 replications are reported in parentheses.

Table 2B: Structural VAR Variance Decompositions

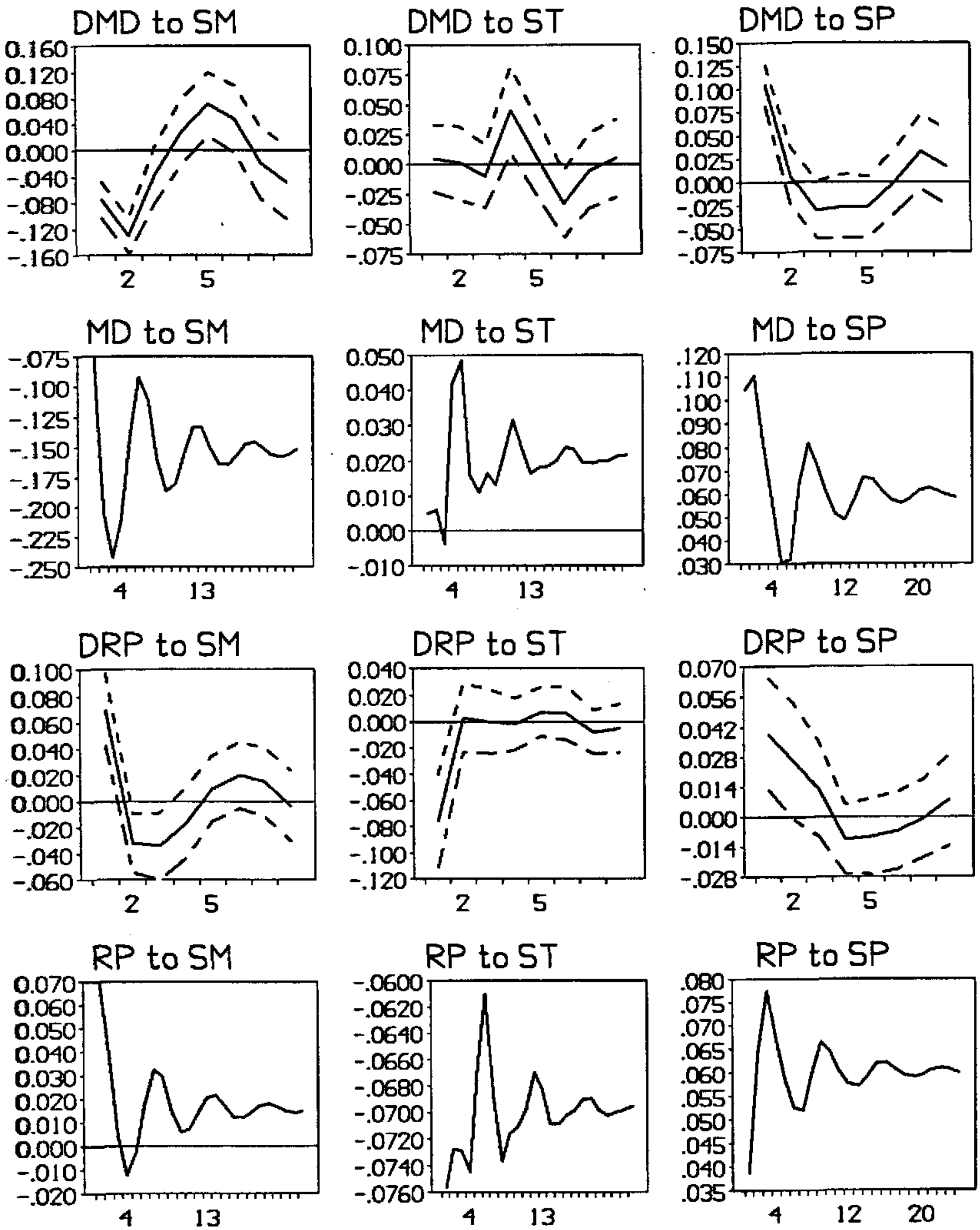
Chinese Hyperinflation: January 1946 to March 1949

Periods Out	Percent of Variance in Rate of Change in Relative Price Due to Shocks in: Money Supply Growth	Transactions Interval	Productivity
1	13.89	33.95	52.16
	(14.2)	(22.3)	(23.9)
2	15.01	32.27	52.72
	(13.5)	(17.1)	(20.9)
3	23.79	25.72	50.48
	(9.0)	(13.5)	(14.6)
6	20.60	40.36	39.04
	(11.9)	(10.1)	(10.3)
12	21.71	40.93	37.36
	(14.3)	(11.0)	(11.6)
24	20.83	41.31	37.86
	(18.0)	(13.2)	(14.9)

Periods Out	Percent of Variance in Rate of Change in Money Demand Due to Shocks in: Money Supply Growth	Transactions Interval	Productivity
1	75.66	3.66	20.67
	(20.7)	(13.2)	(19.6)
2	44.49	42.37	13.13
	(13.7)	(12.2)	(12.2)
3	44.27	42.07	13.66
	(12.9)	(11.0)	(11.8)
6	38.32	42.81	18.87
	(12.6)	(10.2)	(12.5)
12	36.87	44.14	19.00
	(14.7)	(11.3)	(13.2)
24	35.76	44.35	19.88
	(18.1)	(13.5)	(15.5)

Simulated standard errors from 1,000 replications are reported in parentheses.

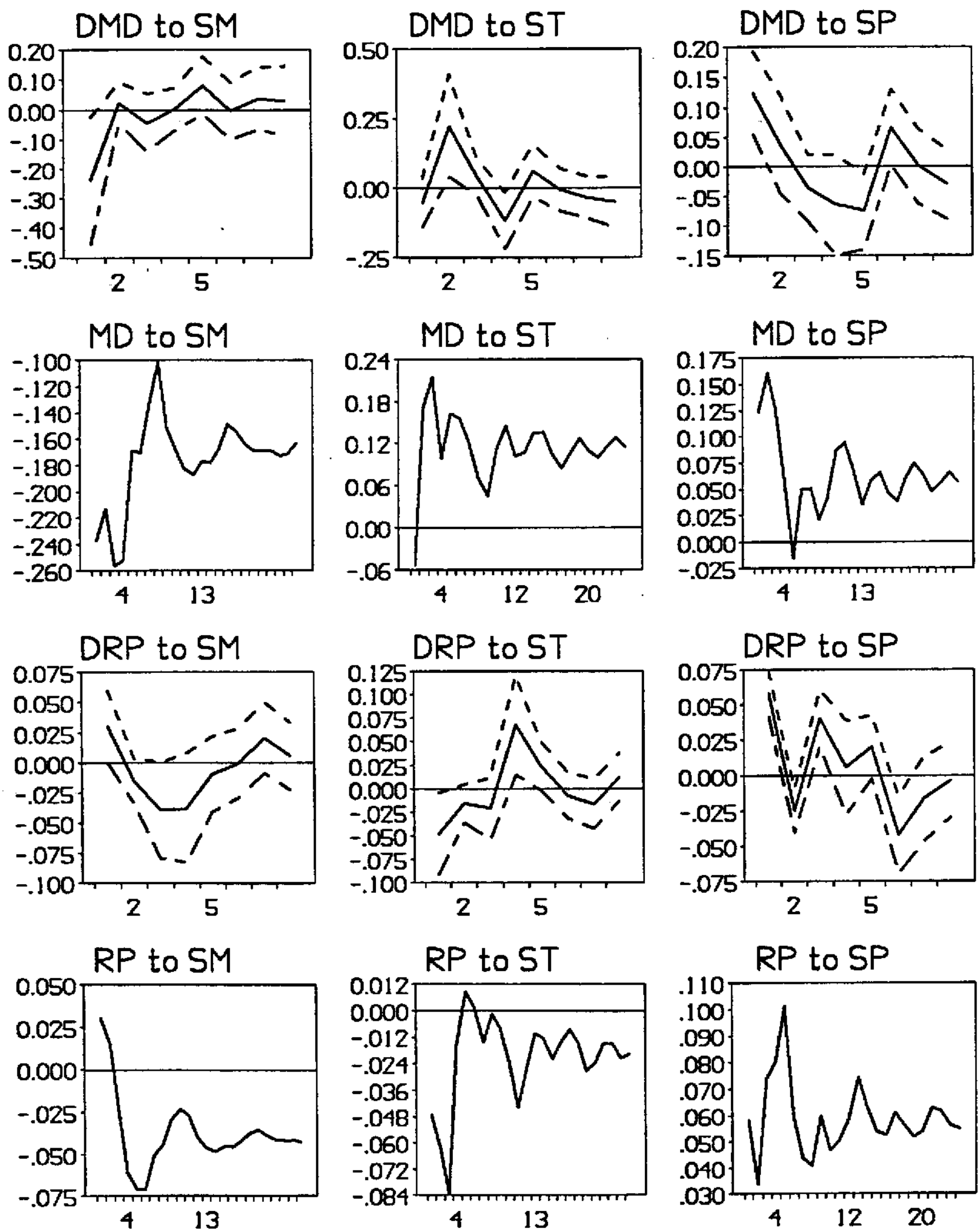
Figure 1A: Impulse Response Functions - Germany



SM - Money Supply Growth Rate Shock
ST - Transactions Interval Shock
SP - Productivity Shock

MD - Money Demand Relative Price Ratio
RP - Relative Price Ratio
DMD, DRP - First Differences of MD, RP

Figure 1B: Impulse Response Functions - China



SM - Money Supply Growth Rate Shock
ST - Transactions Interval Shock
SP - Productivity Shock

MD - Money Demand Relative Price Ratio
RP - Relative Price Ratio
DMD, DRP - First Differences of MD, RP

APPENDIX A

This Appendix displays the algebraic manipulations that we perform to derive the results discussed in the text. Recall the government's money supply process ($\tau_t = \mu_{t+1} m_t$), money market equilibrium ($m_{t+1}/m_t = (1+\mu_{t+1})/(1+\pi_{t+1})$), and the goods market clearing condition ($c_t = y_t$). Using these relations, the generalized CIA constraint ($c_t = v_t\, m_t$), and the first-order conditions for both the firm (2) and the consumer (6)-(8), we find:

$$\beta^{t+1} = E_{t-1}\, \lambda_{1,t} \left[\frac{m_t}{q_t} (1 + \mu_{t+1})\, \gamma + (v_{t+1} - 1) \left[\frac{m_{t+1}}{q_{t+1}} \right] \right]. \tag{A1}$$

By taking ratios, we obtain:

$$\beta\gamma = E_{t-1} \left[\frac{\left[\frac{m_t}{q_t}\right] (1 + \mu_{t+1})\, \gamma + (v_{t+1} - 1) \left[\frac{m_{t+1}}{q_{t+1}}\right]}{\left[\frac{m_{t-1}}{q_{t-1}}\right] (1 + \mu_t)\, \gamma + (v_t - 1) \left[\frac{m_t}{q_t}\right]} \right]. \tag{A2}$$

Also, we have $m_t = c_t/v_t$ and $q_t = \alpha\, a_t\, x^{\alpha-1}{}_t = \alpha\, y_t/x_t = \alpha\, m_t\, v_t/x_t$, implying:

$$\frac{m_t}{q_t} = \frac{x_t}{\alpha\, v_t}\ ;\ x_t = \frac{\alpha\, v_t\, m_t}{q_t}\ ;\ q_t = \alpha^{\alpha}\, a_t \left[\frac{v_t\, m_t}{q_t} \right]^{(\alpha - 1)}.$$

To simplify the analysis, we make the following transformations of the variables. First, we define five growth factors: θ^{μ}, θ^{v}, θ^{a}, θ^{m}, θ^{q} (the money supply growth, the velocity growth, the technology growth, the money demand relative price ratio growth, and the relative price ratio growth, respectively).

$$\theta_t^\mu = \frac{1 + \mu_t}{1 + \mu_{t-1}} \quad ; \quad \theta_t^v = \frac{v_t}{v_{t-1}} \approx \frac{v_t - 1}{v_{t-1} - 1} \quad ; \quad \theta_t^a = \frac{a_t}{a_{t-1}} \quad ; \quad \theta_t^m = \frac{m_t \,/\, q_t}{m_{t-1} \,/\, q_{t-1}} \;;$$

$$\theta_t^q = \frac{q_t}{q_{t-1}} = \theta_t^a \left[\frac{v_t}{v_{t-1}} \; \frac{m_t \,/\, q_t}{m_{t-1} \,/\, q_{t-1}}\right]^{\alpha-1} = \theta_t^a \left(\theta_t^v \, \theta_t^m\right)^{\alpha-1} .$$

Let $\psi_t = (v_t - 1)/(1 + \mu_t)$. We can then rewrite the no-arbitrage equation (A2) as:

$$\beta\,\gamma = E_{t-1}\left[\frac{\dfrac{m_t}{q_t}}{\dfrac{m_{t-1}}{q_{t-1}}}\right]\left[\frac{1 + \mu_{t+1}}{1 + \mu_t}\right]\left[\frac{\gamma + \left(\dfrac{v_{t+1} - 1}{1 + \mu_{t+1}}\right)\left(\dfrac{m_{t+1}/q_{t+1}}{m_t/q_t}\right)}{\gamma + \left(\dfrac{v_t - 1}{1 + \mu_t}\right)\left(\dfrac{m_t/q_t}{m_{t-1}/q_{t-1}}\right)}\right] \tag{A3}$$

$$= E_{t-1}\,\theta_t^m\,\theta_{t+1}^\mu\left[\frac{\gamma + \psi_t\left(\dfrac{\theta_{t+1}^v}{\theta_{t+1}^\mu}\right)\theta_{t+1}^m}{\gamma + \psi_t\,\theta_t^m}\right] \equiv E_{t-1}\,\Delta_t .$$

Consider $\dfrac{\partial \Delta_t}{\partial \cdot}$, evaluated at $\theta^m_t = \theta^m$, $\theta^v_t = \theta^v$, $\theta^\mu_t = \theta^\mu$ (i.e., permanent effect), and $\psi_t = \overline{\psi}$:

$$\frac{\partial \Delta_t}{\partial \theta^m} = [\gamma^2 \theta^\mu + \overline{\psi}\,\theta^m \theta^v (2 + \overline{\psi}\,\theta^m)] / (\gamma + \overline{\psi}\,\theta^m)^2 > 0. \tag{A4}$$

$$\frac{\partial \Delta_t}{\partial \theta^\mu} = \frac{\gamma\,\theta^m}{\gamma + \overline{\psi}\,\theta^m} > 0. \tag{A5}$$

$$\frac{\partial \Delta}{\partial \theta^v} = \frac{\overline{\psi}\,(\theta^m)^2}{\gamma + \overline{\psi}\,\theta^m} > 0. \tag{A6}$$

Straightforward comparative-static analysis using (A4) and (A5) around the steady state generates the following implications:

$$\frac{d\theta^m}{d\theta^\mu} = -\frac{\frac{\partial \Delta^t}{\partial \theta^\mu}}{\frac{\partial \Delta_t}{\partial \theta^m}} = \frac{-\gamma\, \theta^m\, (\gamma + \bar{\psi}\, \theta^m)}{\gamma^2\theta^\mu + \bar{\psi}\, \theta^m\theta^v(2 + \bar{\psi}\, \theta^m)} < 0. \tag{A7}$$

which suggests that increased money supply growth implies decline in the money demand-relative price ratio.

Similarly, using (A4) and (A6), we have:

$$\frac{d\theta^m}{d\theta^v} = -\frac{\frac{\partial \Delta^t}{\partial \theta^v}}{\frac{\partial \Delta_t}{\partial \theta^m}} = \frac{-\bar{\psi}\, (\theta^m)^2\, (\gamma + \bar{\psi}\, \theta^m)}{\gamma^2\theta^\mu + \bar{\psi}\, \theta^m\theta^v\, (2 + \bar{\psi}\, \theta^m)} < 0. \tag{A8}$$

which implies that increased velocity lowers the money demand-relative price ratio.

We can then derive the following relationships for the endogenous relative price variable:

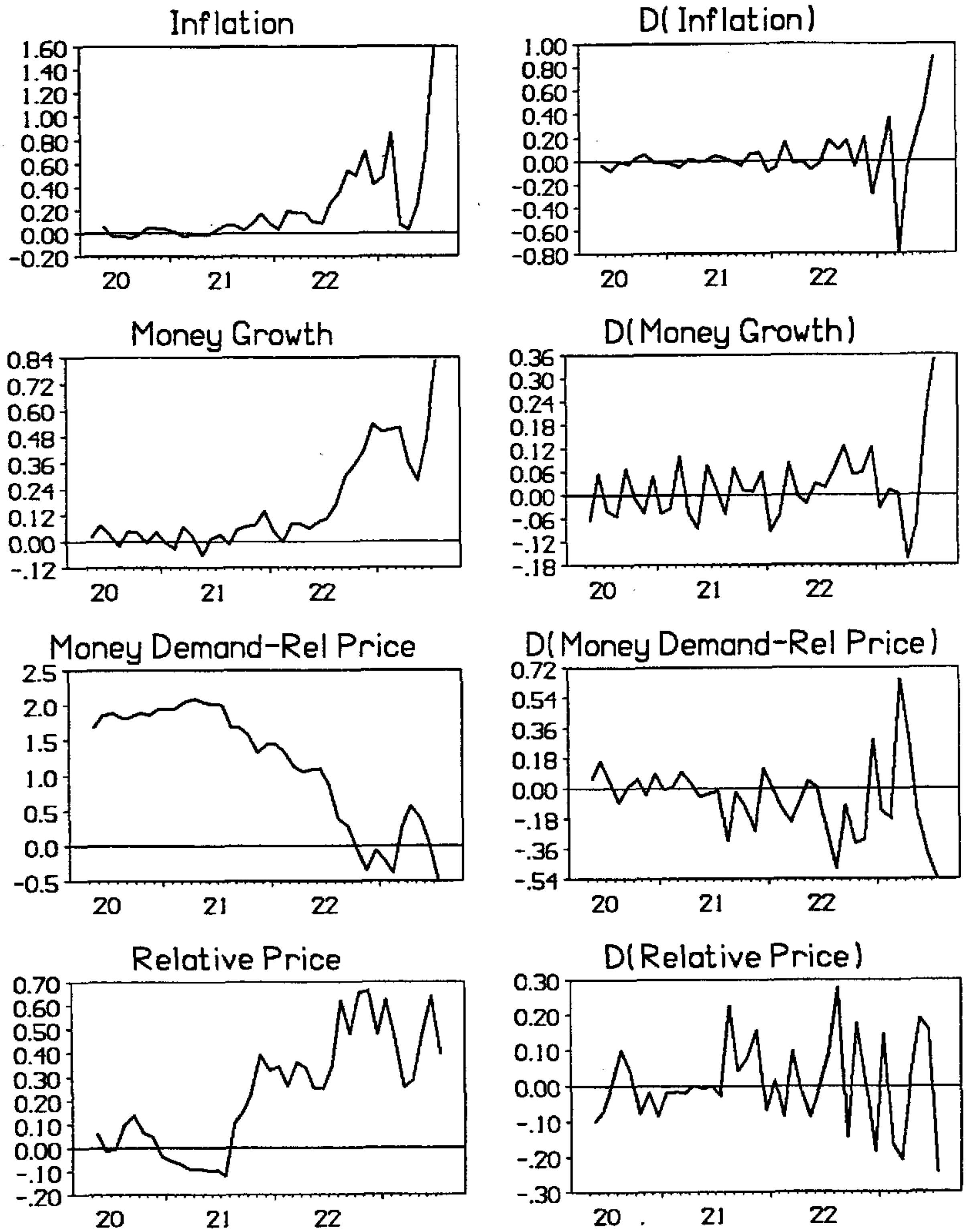
$$\frac{d\theta^q}{d\theta^\mu} = -\frac{\theta^q(1-\alpha)(\theta^m)^{\alpha-2}}{(\theta^v)^{1-\alpha}}\,\frac{d\theta^m}{d\theta^\mu} > 0. \tag{A9}$$

$$\frac{d\theta^q}{d\theta^v} = -(1-\alpha)\frac{\theta^q}{\theta^v}\left[\frac{\gamma^2\, \theta^\mu + \bar{\psi}\, \theta^m\, \theta^v\, (2-\gamma)}{\gamma^2\, \theta^\mu + \bar{\psi}\, \theta^m\, \theta^v(2+\bar{\psi}\, \theta_t^m)}\right] \gtrless 0. \tag{A10}$$

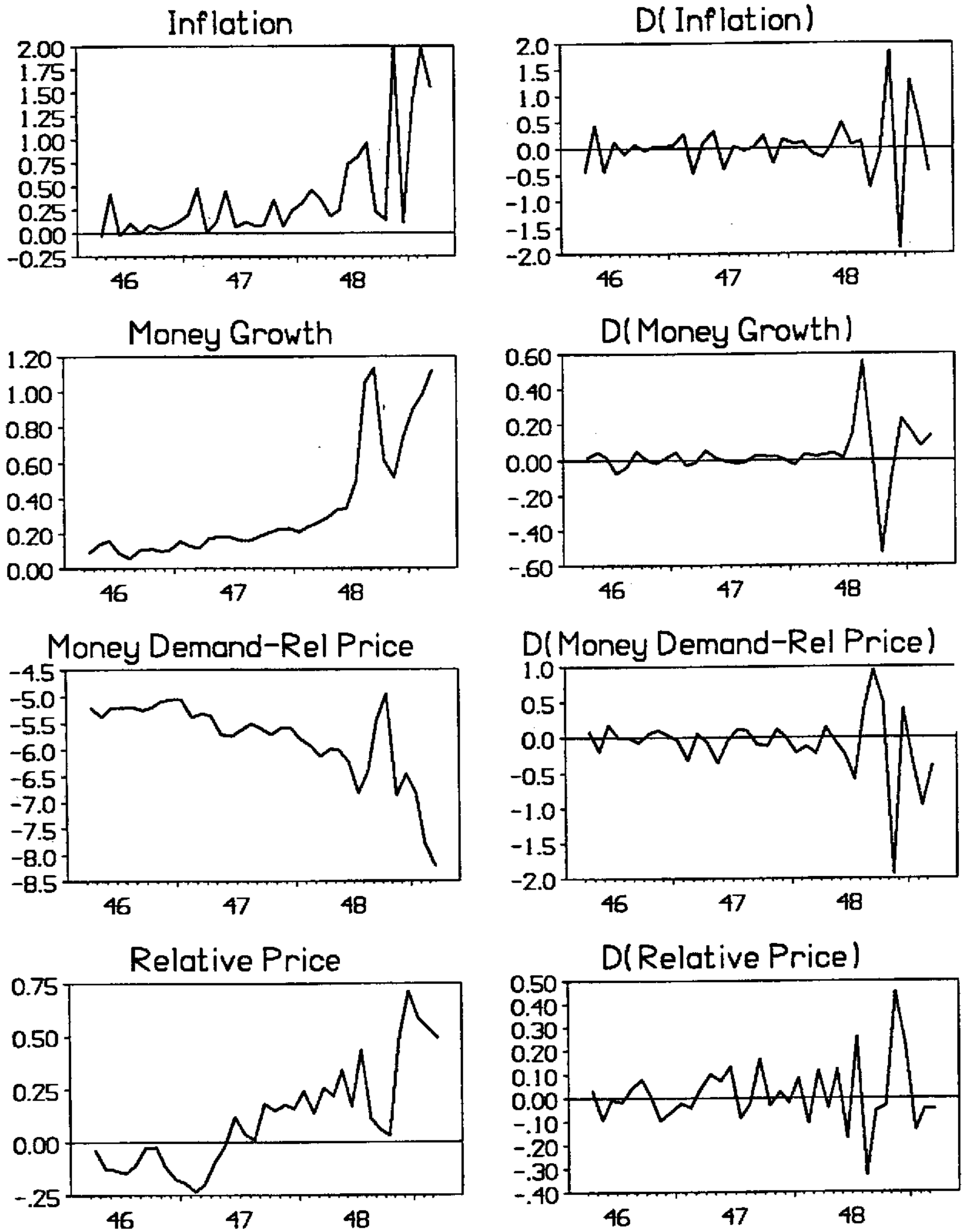
Thus, relative price increases with the money supply, but velocity shocks have ambiguous effects on the relative price.

From these relationships we get support for the implications discussed in the text.

Appendix B
Figure B1: Historical Data - Germany



Appendix B (Continued)
Figure B2: Historical Data - China



APPENDIX C

This appendix summarizes results from an alternative specification and a different identification technique to show the robustness of our main conclusion, that the effect of real disturbances on the money demand behavior is significant during hyperinflationary periods.

First, we collapse the structural VAR to 2 x 2 with money supply growth and real money demand measures only (Dln(MS) and ln(MD), respectively). Then, the change in the rate of money supply growth leaves about 30 or 40 percent of the rate of money demand change unexplained in both Germany and China (see Table C1). We suggest that this leaves a potential role for real disturbances in driving money demand movements. Using Tables 2A and 2B for comparison, we suggest that the two variable results are in line with our full system results. For China, it appears that the innovation associated with both the change in growth rate of money supply and the rate of change in money demand proxies for the excluded real shock variable. In Germany, the explanatory power of real shocks seem captured in the money demand shocks.

Second, we also identify a three variable VAR using the identification methods developed in Sims (1980), and employing our ordering. We note that due to the identification technique, we are not able to truly identify what is the "shock associated to the relative price ratio" on money demand growth. Bearing in mind the caveat, shocks associated to relative price account for about 34 and 16 percent of the variance in the rates of money demand change in Germany and China, respectively (see Table C2). Moreover, these results remain when the relative price ratio is placed first in the ordering (see Table C3). Despite the ambiguity of the identification method, we take these results as evidence in support of the robustness of our structural findings.

Table C1: Variance Decomposition (2 X 2 Model)

German Hyperinflation

Periods Out	Percent of Variance in Rate of Change in Money Demand Due to Shocks in: Money Supply Growth	Money Demand
1	62.00	38.00
3	71.35	28.65
24	69.62	30.38

Chinese Hyperinflation

Periods Out	Percent of Variance in Rate of Change in Money Demand Due to Shocks in: Money Supply Growth	Money Demand
1	97.26	2.74
3	62.66	37.34
24	57.33	42.67

Table C2: Variance Decomposition (Sims' Method: Order MGR-MRP-RP)

German Hyperinflation

Periods Out	Percent of Variance in Rate of Change in Money Demand Due to Shocks in: Money Supply Growth	Transactions Interval	Productivity
1	12.85	56.52	30.63
3	13.22	52.81	33.97
24	13.26	52.83	33.91

Chinese Hyperinflation

Periods Out	Percent of Variance in Rate of Change in Money Demand Due to Shocks in: Money Supply Growth	Transactions Interval	Productivity
1	21.29	70.18	8.52
3	43.25	40.68	16.06
24	45.30	38.99	15.71

Table C3: Variance Decomposition (Sims' Method: Order RP-MGR-MRP)

German Hyperinflation

Periods Out	Percent of Variance in Rate of Change in Money Demand Due to Shocks in: Money Supply Growth	Transactions Interval	Productivity
1	13.41	85.32	1.27
3	15.30	50.19	34.51
24	15.34	50.11	34.54

Chinese Hyperinflation

Periods Out	Percent of Variance in Rate of Change in Money Demand Due to Shocks in: Money Supply Growth	Transactions Interval	Productivity
1	17.78	77.91	4.31
3	34.43	45.71	16.86
24	39.20	43.52	17.28

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