Inflation, Disinflation, and Deflation in China:

Identifying the Shocks Driving Inflation*

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ABSTRACT

The time profile of inflation in China over the past 15 years resembles the one experienced in major industrial countries over a 40-year period. Some observers claim that the deflation in China, in particular, may have been driven primarily by aggregate supply factors, especially strong productivity growth. Others are more skeptical.

We follow the usual approach of estimating small order vector autoregressions (VARs). However, in view of the uncertainty surrounding the sources of economic shocks, this paper compares results from three sets of alternative identification conditions, namely the standard Blanchard-Quah approach, an approach recently proposed by Cover, Enders, and Huang (2005), as well as the set of identifying restrictions considered by Bordo, Landon-Lane and Redish (2004) used to study economies in deflation from an historical perspective. In this fashion we are able to test for sensitivity to different identification assumptions.

Our principal finding is that inflation in China has been primarily driven by aggregate demand factors. Nevertheless, the results can be sensitive to the identification restrictions. Interestingly, we find that while aggregate supply factors may have pushed inflation to cross the threshold leading to deflation, monetary policy is primarily responsible for Chinese macroeconomic outcomes. More importantly, one can only conclude that China's deflation was supply-driven if AS and AD disturbances are assumed to be uncorrelated, as assumed in the oft-used Blanchard-Quah decomposition, and this appears to be an unappealing assumption in the present context.

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1. Introduction

The time profile of inflation in China over the past 15 years resembles the one experienced in major industrial countries over a 40-year period. Figure 1 makes the point graphically by comparing the US experience over the past 40 years against China's inflation since 1990. Negative aggregate supply shocks during the 1970s, combined with an inappropriate monetary policy response, are believed to explain the spike in inflation in the early 1980s in the US. The low and stable inflation rates since the 1990s is the product of the recognition of the importance of price stability, combined with good aggregate demand management (e.g., see Orphanides 2003). In contrast, the deregulation of prices in the early 1990s may well have contributed to the rapid rise of inflation in China that was facilitated by an accommodative monetary policy. Either productivity growth, monetary policy, or both, have been advanced as arguments to explain the rapid disinflation and deflation during the second half of the 1990s. Some observers (e.g., Bernanke 2002, Cargill and Parker 2004) claim that the deflation in China, in particular, may have been driven primarily by aggregate supply factors, especially strong productivity growth. Others (e.g., Burdekin and Siklos 2004) are more skeptical. There is a subtle difference of opinion therefore about whether the deflation in China was primarily driven by aggregate demand (AD) or supply (AS) factors. While industrial countries have undergone several monetary policy regime changes over the past forty years the policy regime in China has remained largely unchanged over the period considered.

Whether inflation in China is explained by aggregate demand or aggregate supply factors has important broader implications for our understanding of the role of monetary policy. Moreover, if the disinflation and deflation are driven primarily by aggregate supply factors, this suggests that the recent Chinese macroeconomic experience stands in contrast with Japan's recent deflation induced slump.[1]

Deflation, of course, is a topic that has received considerable attention lately. Often, deflation is associated with economic contraction. An alternative view suggests that productivity and technological changes lead to an expansion of aggregate supply relative to aggregate demand thereby leading to lower prices while economic activity expands. Bernanke (2002), a governor of the US Federal Reserve, remarked: "I don't know of any unambiguous example of a supply-side deflation, although China in recent years is a possible case." Generally, however,

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[1] There is, of course, a vast literature on the Japanese experience with deflation. A partial list would include, for example, Hutchison (2004), Kuttner and Posen (2004), Okina and Shiratsuka (2004), Hetzel (1999), and Krugman (1998).

most observers associate deflation with bad economic outcomes (Burdekin and Siklos 2004, Bordo and Filardo 2004).

One way to explore the forces driving inflation in China is to examine the relative importance of aggregate demand versus aggregate supply factors. We follow the usual approach of estimating small order vector autoregressions (VARs). However, in view of the uncertainty surrounding the sources of economic shocks, this paper compares results from three sets of alternative identification conditions, namely the standard Blanchard-Quah approach, an approach recently proposed by Cover, Enders, and Huang (2005), as well as the set of identifying restrictions considered by Bordo, Landon-Lane and Redish (2004) used to study economies in deflation from an historical perspective. In this fashion we are able to test for sensitivity to different identification assumptions.

Our estimated models are either bivariate, consisting or real GDP and inflation, or trivariate, consisting of real GDP, inflation and money or credit growth. Data and sample limitations constrain model complexity under the circumstances. Money or credit growth are used to proxy the direct effects of monetary policy since institutional considerations imply that an interest rate instrument is unsuitable in China's case.

Our principal finding is that inflation in China has been primarily driven by aggregate demand factors. Given that the People's Bank of China (PBC) has a history of announcing monetary targets (generally in terms of an aggregate such as M2), our results are consistent with the view that the conduct of monetary policy is central to understanding the behavior of inflation, disinflation, and deflation in China.

Monetary aggregates have tended to take a back seat of late to interest rates, in models of monetary policy. Estimation, say, of a Taylor rule would not be sensible in China's case as the PBC does not have an interest rate target and several other key interest rates are largely administratively determined. More recently, Fatas, Mihov and Rose (2004) provide evidence suggesting that central banks with a monetary target generate, on average, lower inflation. China's experience adds new evidence that central banks which neglect monetary factors, in understanding the course of inflation, do so at their own peril.

To be sure, the results shown below can be sensitive to the identification restrictions. Interestingly, we find that while aggregate supply factors may have pushed inflation to cross the threshold leading to deflation, monetary policy is primarily responsible for Chinese macroeconomic outcomes. More importantly, one can only conclude that China's deflation was supply-driven if AS and AD disturbances are assumed to be uncorrelated, as assumed in the oft-

used Blanchard-Quah decomposition, and this appears to be an unappealing assumption in the present context.

The paper is organized as follows. First, we provide an overview of economic performance and the role of monetary policy in China. Section 2 provides a review of the literature on deflation with an emphasis on the Chinese experience. The econometric technique used in the paper, and the various identification assumptions invoked, is discussed in Section 3. Section 4 provides a description of the data together with model estimates and their interpretation. Section 6 concludes.

2. Deflation in China and Elsewhere: An Overview

2.1 China's Overall Economic Performance

Over the past decade or more, the Chinese economy has consistently maintained rapid economic growth. The results are reflected in the rather remarkable levels of growth in both real GDP and industrial production, shown in Figure 2. While there has been some debate about the accuracy of Chinese macroeconomic data (e.g., see Rawski 2002, Prasad 2004) few would disagree that overall economic growth over the period in question has been impressive. Annual growth rates in real GDP appear particularly volatile, more so than experienced by industrial economies. However, real GDP growth performance does not appear atypical when the basis of comparison is an emerging market economy.

In the econometric analysis to follow, both output series were also converted into output gap type proxies, the usual practice in the relevant literature. A variety of filters, including cubic trends, HP filters and broken trends were examined. The series plotted in Figure 3 are representative of the various outcomes obtained. Broadly speaking, the type of filter does not seem to matter greatly except toward the end of the sample when the HP filter and cubic trends suggest that both real GDP and industrial production are below trend.[2] When the output gap in terms of industrial production is estimated via an HP filter economic activity is above trend toward the end of the sample. Differences are more pronounced as between output measures. Moreover, during the disinflation and deflation portions of the sample (1995 to 2004), the output gap based on industrial production is typically positive whereas the real GDP version is closer to trend much of the time.

As recent monetary policy and exchange rate developments in China have been ably described elsewhere (e.g., Cargill and Parker 2004, Wang 2004, Dai 2002) we simply point out

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[2] A well-known problem with the HP filter is its sensitivity to the end-points of the sample. See, for example, Dupasquier, Guay and St.-Amant (1999).

that the People's Bank of China relies primarily on the control of monetary aggregates, less so on an interest rate instrument, to send signals about its intentions.[3] Figure 4 plots narrow and broad money growth measures and the benchmark interest rate level in China since 1991. There is considerably more variation in the monetary aggregates than in interest rates over the sample considered while the money growth proxies reveal somewhat different time profiles. The summary statistics in Table 1 suggest a clear demarcation between the eras of inflation (1990-1994) and disinflation (1995-2004) in both inflation and output growth performance. The disinflation period also includes a period lasting about five years when the economy was in deflation.[4] The data also suggest that economic growth slowed considerably during the second half of the sample considered. Interestingly, the average output gap based on industrial production is clearly positive during the inflation sample, and negative when only the disinflation and deflation data are considered. Almost two-thirds of the sample considered in this study consists of disinflation and deflation while over a third of the data cover a period of deflation, defined here as negative inflation.

2.2 Global experience with Deflation

Sustained economic growth in a deflationary environment suggests the apparent uniqueness of China's deflation. Nevertheless, worries over the consequences of deflation first emerged in China in April 1998 on the back of the Asian financial crisis. China then faced continuous weak domestic demand and an appreciation in the currency, the renminbi (RMB). The deflation lasted for two years until May 2000, with the CPI once registering the largest monthly decline of 2.2%. Prices began to climb slowly for the next year and a half. Exports and Foreign Direct Investment (FDI) stimulated economic growth along with a fiscal stimulus. Deflation returned in September 2001. Until September of 2002, the CPI was down by 0.8% over the previous year and the negative rate of change in the CPI lasted until the beginning of 2003. Consumer goods, food and non-food items all recorded price decreases while service items recording a small increase.

Productivity gains also explain the significant structural change in the Chinese economy over this period stemming from market-oriented reforms, heavy direct foreign investment into

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[3] See, for example, www.pbc.gov.cn/english/huobizhengce/instruments.asp, and People's Bank of China (2003, 2004).

[4] Negative inflation rates were actually recorded in 1998-99 and 2001-02. However, even when positive inflation rates were recorded in 2000 and 2001, these were well below 1% (except in 2001Q2 when the inflation rate was 1.10%). Hence, it is not inaccurate to state that China experienced deflation during the 1998-2002 period.

China, export growth from the advantage of relatively low wages, and a highly competitive exchange rate. Surging FDI, government spending, and exports, also contributed to economic growth in China during this period. Moreover, rising investment in technology also assisted productivity with annual productivity gains estimated to be 4%-5%.

Yu (1997) outlines the background of China's macroeconomic policy and assesses the effectiveness of monetary and fiscal policy control in particular. He examines the long-term relationship between a number of macroeconomic variables and economic activity from 1983:12-1994:05. Employing a variety of vector error-correction models (VECMs) that include variables such as money aggregates, bank credit, output and prices in the empirical estimation, he argues that tight monetary management in the early transition period played an important role in influencing the economic cycle. However, monetary policy showed no significant impact on fixed-asset investment, retail sales to institutions and merchandise imports. The reasons are that the highly centralized bank-credit controlling system, the lack of independence of the central bank from government, showed up in the high deposit costs and huge non-performing loans that are on the books of the banking sector.

Woo (2003) focuses on the current macroeconomic and exchange rate management in China and provides an overview of the various signals of macroeconomic "overheating" and deflation experienced during the economic transition to a more market-driven economy. He argues that the roots of deflation pressure in China are the inadequate market-based macroeconomic reforms, and the continued unbalanced credit structure between the government or public sector vis-á-vis the domestic private sector. Consequently, existing savings are inefficiently intermediated through the monopoly state banks.

Cargill and Parker (2004) is one of the few studies to have specifically examined China's deflation. They argue that the recent deflation in China may supply have been supply-led. They associate the high rate of real GDP growth, loose monetary and fiscal policies, and ongoing structural changes in the economy as playing important roles in explaining the deflation. As a result, China's deflation was not harmful to the economy. They estimate a money demand function using quarterly data since 1960, and their empirical results show that the deflation had no measurable impact on money demand. Such a result is inconsistent with the People's Bank of China's (PBC) view that the recent aggressive monetary policy is the key reason China has overcome the slowdown in the Asian economic zone, beginning with the Asian crisis of the late 1990s.

More general overviews of the impact of deflation on macroeconomic fluctuations have also appeared recently. They include: Borio and Filardo (2004), Burdekin and Siklos (2004), and Bordo and Filardo (2004). These studies document the behavior of prices by focusing on the frequency, severity, duration, persistence and cross-country correlations of deflation since the 19th century. Borio and Filardo (2004) find that the economic cycle that has accompanied some of the deflationary episodes may be associated with significant costs to the real economy. Moreover, as long as the deflation rate remains mild, there is no reason to expect that deflations should necessarily be associated with economic weakness. Instead, economic expansion may result. A similar argument is made in Burdekin and Siklos (2004) who conclude that most historical experiences with deflation were driven by aggregate demand shocks while it seems difficult to find unambiguous examples of a supply side driven inflation. Bordo and Filardo (2004) consider the historical record and find that fears of deflation can be overblown. Nevertheless, there are asymmetries in economic performance between inflation and deflation, and policymakers need to be aware of the rules of slipping into a prolonged deflation.

It is apparent from the historical experience that one needs to distinguish between at least two forms of deflation, namely the "good" and the "bad" varieties.[5] A "good" deflation takes place when productivity and technological changes result in an expansion of aggregate supply relative to aggregate demand thereby leading to falling prices. "Good" deflations reflect innovations against the background of underlying or secular restraints on the growth of nominal demand. This can lead to stronger economic growth, buoyant asset prices, and a healthy rate of expansion of monetary and credit aggregates. Hence, deflation can have a positive impact on economy (e.g., See Selgin 1997).

For example, DeLong (1997), drawing on the work of Viner (1933) and Hayek (1931) argues for a role for productivity growth and its impact on the economic cycle. He argues that in an economy with constant productivity, a stable price level contributes to macroeconomic stability in a number of ways. In particular, expectations of zero inflation lessen the chance of accounting a "bad" deflation. Further, by contributing to the efficiency of fixed nominal wage and debt contracts, as well as by minimizing the burden of monetary policy adjustment borne by the price system, the economy is less prone to going into a depression. However, a stable price level is far from being ideal in an economy with changing productivity. The reason is that if productivity is not constant, a stable price level does not guarantee the stability of nominal

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[5] A third variety, labeled "ugly", is not explicitly considered here as it refers to the rather unique episode of the Great Depression.

spending and the efficiency of fixed nominal contracts. As a result, macroeconomic stability is not assured. Instead, stability of final demand requires a rate of deflation equal to minus the rate of productivity growth. Clearly, a steady growth in productivity will lead to a booming economy.

In contrast, "bad" deflations are usually associated with a slumping economy. As a result, serious economic weaknesses become apparent. Bernanke and Carey (1996), and Akerlof, Dickens, and Perry (1996), argue that deflation due to nominal wage rigidities can interfere with efficient economic adjustments in labor markets, prolonging and deteriorating economic contractions, which can ultimately reinforce poor economic performance in a deflationary economy. Moreover, debt deflation, an idea that can be traced to Fisher (1933), can undermine real economic activity by increasing the cost of servicing outstanding debt obligations. The deterioration in the financial condition of borrowers leads to cuts in spending, thereby sapping the financial quality of lenders and exacerbating access to external financing.

Borio and Filardo (2004) argue that deflations stemming from the impact of negative demand shocks are also of the "bad" variety since negative output effects accompany such events. Examples include the Great Depression (1929-33), the recession of 1919-21, and the modern-day case of Japan. Although deflations typically originate with a monetary contraction, as predicted by the quantity theory, there is little long-run impact of aggregate demand shocks on output and prices, providing evidence for the importance of understanding aggregate demand-driven deflation for the economy. More importantly, it seems clear that economic performance is ultimately traceable to the quality of the monetary policy being pursued.

3. Identifying Aggregate Demand and Supply Shocks in China

To empirically examine good versus bad deflation dichotomy in the Chinese context, a sensible approach is to estimate aggregate demand and supply shocks and determine their relative importance. Arguably, the most popular method of identifying such factors in the methodology is due to Blanchard and Quah (1989).

The Blanchard-Quah approach has been used to examine the dynamic effects of economic innovations. The technique consists in estimating a VAR system that includes at least two endogenous variables, imposes the necessary restrictions to identify two types of disturbances that are then interpreted as aggregate demand and aggregate supply shocks. By imposing different identification restrictions, the permanent or temporary effects of these two shocks and their economic interpretation can be estimated. Other research has extended BQ

methodology to examine the contribution of either type of shock by employing a different set of restrictions.

Cover, Enders and Hueng (2005) specify a standard AD-AS model by examining the linear relationship between shocks with causality running either from supply shocks to demand shocks, or vice-versa.

Their normalization restrictions differ from BQ's methodology in important ways. They argue that it is not necessary to assume that the structural shocks are mutually uncorrelated. Instead, aggregate demand and supply are seen as moving together through time. The impact of supply shocks on output will then depend on the relationship between aggregate demand and supply shifts.

The bivariate approach is, of course, a restrictive one. Bordo and Redish (2004) argue that a simple demarcation between good and bad deflation does not capture the complexity of the historical experience. They focus on the price level and growth experience of the US and Canada over the deflationary period 1870-1913. Using annual data, they then proceed to identify different supply, monetary policy and aggregate demand shocks, and impose three different sets of restrictions in the context of the BQ methodology. In this paper we adopt a similar methodology to theirs to explore the Chinese inflationary experience (also see Bordo, Landon-Lane and Redish 2004).

4.1 Identification methodology I: The Benchmark BQ model

Two types of disturbances affect output and inflation. Aggregate supply disturbances have a long run effect on either inflation and or output. Aggregate demand disturbances are assumed to have no long run effect on inflation, but may have a long run effect on output. Finally, these two disturbances are uncorrelated at all leads and lags. To derive the joint process let ΔP and ΔY, respectively, denote price and output level that have been differenced to achieve stationarity.[6] Therefore, the resulting bivariate VAR is written:

$$\begin{bmatrix} \Delta P_t \\ \Delta Y_t \end{bmatrix} = \begin{bmatrix} \Delta P_0 \\ \Delta Y_0 \end{bmatrix} + \begin{bmatrix} a_{11}(L) & a_{12}(L) \\ a_{21}(L) & a_{22}(L) \end{bmatrix} \begin{bmatrix} \Delta P_t \\ \Delta Y_t \end{bmatrix} + \begin{bmatrix} e_{pt} \\ e_{yt} \end{bmatrix} \tag{1}$$

where e_{pt} and e_{yt} are the random disturbances in the price and output level equations and they reflect a linear combination of the underlying structural shocks that are responsible for variations

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[6] In the case of output an alternative that is often preferred is to use a proxy for the output gap. This approach is also followed below.

in P_t and Y_t. Following earlier studies, one of these structural shocks is assumed to be a supply shock, ε_s, while the other is demand shock, ε_d, so that residuals vector is defined as:

$$\begin{bmatrix} e_{pt} \\ e_{yt} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix}\begin{bmatrix} e_d \\ e_s \end{bmatrix} \tag{2}$$

Following the BQ methodology, the first three restrictions are on the four elements of A (0), where for any matrix A (0) such that A (0) A (0)'= Ω is an orthogonal transformation of a lower triangular Choleski factor of Ω, the upper right entry a_{12} (j), j=1,2,..., sums to zero. Since the two disturbance e_{pt} and e_{yt} are assumed to be uncorrelated in the standard BQ model, the variance covariance matrix is diagonal and covariance matrix is identity. Therefore, we can write:

$$\begin{bmatrix} \mathrm{var}(e_{yt}) & \mathrm{cov}(e_{yt}\, e_{pt}) \\ \mathrm{cov}(e_{yt}\, e_{pt}) & \mathrm{var}(e_{pt}) \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix}\begin{bmatrix} \sigma_{\varepsilon_s}^2 & \sigma_{\varepsilon_s\varepsilon_d} \\ \sigma_{\varepsilon_s\varepsilon_d} & \sigma_{\varepsilon_d}^2 \end{bmatrix}\begin{bmatrix} c_{11} & c_{21} \\ c_{12} & c_{22} \end{bmatrix} \tag{3}$$

According to the above description, the restriction $\sigma_{\varepsilon_s}^2 = \sigma_{\varepsilon_d}^2 = 1$ ensures that the variance of the demand and supply shocks are equal, while the condition $\sigma_{\varepsilon_s\varepsilon_d} = 0$ implies that the types of shocks are uncorrelated. Finally, the restriction $\sum_{j=0}^{\infty} a_{12}(j) = 0$ means that demand shocks, ε_d, have no permanent effect on output.

3.2 Identification methodology II: Modified BQ Model

The assumption that demand and supply shocks are uncorrelated is implausible for the Chinese case because the monetary and fiscal authority acted in tandem in the context of national targets for economic growth. Hence, relying on the methodology of Cover, Enders and Hueng (2005) and relax the restriction that AD and AS shocks are uncorrelated.

These restrictions cannot be accommodated in the Benchmark BQ model. Therefore, the responses of output and the price level need to be re-estimated, allowing the disturbances to be correlated. Let Y_t and P_t denote the logarithm of output and the logarithm of price level respectively during period t, while $_{t-1}Y_t$ and $_{t-1}P_t$ represent the level of expected output and price level given the information at the end of period t. A simple AD-AS model can be written as:

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$$Y_t^s = {}_{t-1}Y_t + \alpha(P_t - {}_{t-1}P_t) + \varepsilon_s$$
$$(Y_t + P_t)^d = {}_{t-1}(Y_t + P_t)^d + \varepsilon_d \qquad (4)$$
$$Y_t^d = Y_t^s$$

As identified in the benchmark BQ model, ε_s is the aggregate supply shock and ε_d is the aggregate demand shock. However, the relationship between these shocks is no longer assumed to be uncorrelated. Therefore, $\sigma_{\varepsilon_s \varepsilon_d} \neq 0$ and there is one less restriction than in the BQ decomposition. Two alternatives are available. First, if the relationship runs from AS shocks to AD shocks the relationship can be written as:

$$\varepsilon_d = \beta\varepsilon_s + \varepsilon_{d_0} \qquad (5)$$

where ε_d is the linear combination of pure AD shocks ε_{d_0} and the induced change from the AS shocks is $\beta\varepsilon_s$; β is the weight of temporary AS shocks that can result in a contemporary change in aggregate demand. Covers, Enders and Huang (2005) show that the BQ decomposition applied to model (4) is equivalent to assuming that correlation runs from shifts in AS to shifts in AD. A plausible scenario is one where the monetary authorities see an aggregate supply shock and react to it within the same quarter. The reaction need not, of course, be complete as β><1. Equation (5) has two characteristics that are applicable to the Chinese case. An aggregate supply shock may be attributed to the rapid productivity growth in China in the sample considered. Consequently, an oversupply of output is possible. Therefore, assuming the Chinese deflation was driven by a positive aggregate supply shock, the monetary authority's response of cutting interest rates and bringing aggressive monetary policy into force (e.g., see Figure 4) can be explained as an attempt to increase aggregate demand to stabilize the price level and prevent deflation.

The second possibility is that the link runs from AD shocks to AS shocks in which case the relationship can be written as:

$$\varepsilon_s = \gamma\varepsilon_d + \varepsilon_{s_0} \qquad (6)$$

Hence, the parameter γ depends on the degree of price rigidity in the economy. Firms do not fully adjust price in response to some unexpected demands shock and continue to oversupply the output demanded. There is a good case to be made that China's policies are consistent with this possibility as well. After all, China is not a full-fledged market economy, and there is substantial government involvement in the economy in the form of aggressive aggregate demand

management. Lastly, the well documented problems with the banking sector, dominated by state-owned banks and, consequently, strongly influenced by PBC policies, may also contribute to a link going from AD to AS.

As in the BQ model, it is still assumed that structural demand and supply shocks are orthogonal in this bivariate VAR system. However, the variances of AD and AS shocks are no longer restricted to unity. Therefore, the estimation of the VAR yields the following variance-covariance representation:

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\begin{bmatrix} \text{var}(e_{yt}) & \text{cov}(e_{yt}e_{pt}) \\ \text{cov}(e_{yt}e_{pt}) & \text{var}(e_{pt}) \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} \begin{bmatrix} \sigma^2_{\varepsilon_s} & \sigma_{sd} \\ \sigma_{sd} & \sigma^2_{\varepsilon_d} \end{bmatrix} \begin{bmatrix} c_{11} & c_{21} \\ c_{12} & c_{22} \end{bmatrix} = \begin{bmatrix} \dfrac{1}{1+\alpha} & \dfrac{\alpha}{1+\alpha} \\ \dfrac{-1}{1+\alpha} & \dfrac{1}{1+\alpha} \end{bmatrix} \begin{bmatrix} \sigma^2_{\varepsilon_s} & \sigma_{sd} \\ \sigma_{sd} & \sigma^2_{\varepsilon_d} \end{bmatrix} \begin{bmatrix} \dfrac{1}{1+\alpha} & \dfrac{-1}{1+\alpha} \\ \dfrac{\alpha}{1+\alpha} & \dfrac{1}{1+\alpha} \end{bmatrix} \quad (7)
$$

where $\sigma^2_{\varepsilon_s}$ is the variance of the structural supply shock and $\sigma^2_{\varepsilon_{d0}}$ is the variance of pure AD shocks, which is independent of AS shocks.

Following Cover, Enders and Hueng (2005), three independent restrictions are imposed. They are: $c_{11} = \alpha \, c_{12}$, $c_{11} = -c_{21}$ and $c_{11} = c_{22}$, as well as the long run neutrality restriction that AD shocks have no long run impact in output. The structural parameters obtained from such restrictions will be used to explain the slope of aggregate supply curve, α; the effect of the structural AD shocks on output, $\dfrac{\alpha}{1+\alpha}$ and the effect of AS shocks on output, $\dfrac{1}{1+\alpha}$. It is important to note, as do Covers et al., that ε_d now represents unexpected aggregate demand since ε_d is not independent of ε_s as would be assumed under the BQ decomposition.

3.3 Identification methodology III: Tri-variate VAR model

With only two endogenous macroeconomic variables, it is arbitrary to conclude that AD shocks have no effects on the changes in the price level without exploiting more information from other available macroeconomic variables. One possibility is that of a "productivity-driven deflation", as suggested by Cargill and Parker (2004), and further discussed by Bordo Landon-Lane and Redish (2004). In addition, with the disinflation and deflation phase beginning around 1995:1, alternative sample estimation is required to determine the accompanying impact in each sub-sample.

We proceed by modeling the joint behavior of the price, output and money stock in China from 1990 to 2004 by adapting the BQ decomposition methodology to the case of a trivariate VAR. Let ΔP again denote inflation, ΔY the growth of real GDP, and ΔM is growth in the money stock. Three stochastic disturbances are estimated, namely a money supply shock,

ε_{ms}, an aggregate supply shock, ε_s and demand shock, ε_d. Next, we impose long-run restrictions on the impact of the shocks on prices and output. The resulting VAR includes prices, output and money stock is written as follows:

$$\Delta y_t = D_t \alpha + \sum_{j=1}^{p} B_j \Delta y_{t-j} + \varepsilon_t \qquad (8)$$

where $y_t = (P_t, Y_t, M_t)'$ and D_t is a matrix of deterministic variables that includes a constant, a dummy to identify a regime shift, or possibly a time trend. The data are differenced (or de-trended) to ensure stationarity. Following the BQ approach, a set of structural innovations, u_t, that are orthogonal to each other can be obtained from this reduced VAR specification from:

$$\varepsilon_t = C u_t \qquad (9)$$

We identify C by imposing three alternative long-run restrictions on the structural impulse response functions implied by the reduced form VAR to examine the impact of each shock that drives the joint behavior of prices, output and the money stock.

A first set of restrictions assumes that an aggregate demand shock is an aggregation of money demand shocks and temporary spending shocks that have a zero long-run impact on output and prices. The money supply shock is defined to be non-neutral, indicating a positive monetary shock will increase output in the long run. Fluctuations in the price level are attributed to the change in money supply shocks but the temporary or permanent impact of these shocks on price, output, and the money stock, is not restricted. Aggregate supply shocks are expected to lower the price level and increase the output in the short run but a rise in aggregate demand will then raise the price level until it returns to its original level. Therefore, assuming the structural innovation vector is ordered as $u_t = (\varepsilon_{ms}, \varepsilon_s, \varepsilon_d)'$ then the long run restriction can be written

$$\begin{bmatrix} \Delta P \\ \Delta Y \\ \Delta M \end{bmatrix} = \begin{bmatrix} c_{11}(1) & 0 & 0 \\ c_{21}(1) & c_{22}(1) & 0 \\ c_{31}(1) & c_{32}(1) & c_{33}(1) \end{bmatrix} \begin{bmatrix} \varepsilon_{ms} \\ \varepsilon_s \\ \varepsilon_d \end{bmatrix} \qquad (10)$$

Since there are three zero restrictions the system is exactly identified.

An alternative long-run restriction consists in assuming that money is neutral, which implies that the long-run impact of a money supply shock on output is zero. Therefore, this leads to a system of the form:

$$\begin{bmatrix} \Delta P \\ \Delta Y \\ \Delta M \end{bmatrix} = \begin{bmatrix} c_{11}(1) & 0 & 0 \\ 0 & c_{22}(1) & 0 \\ c_{31}(1) & c_{32}(1) & c_{33}(1) \end{bmatrix} \begin{bmatrix} \varepsilon_{ms} \\ \varepsilon_{s} \\ \varepsilon_{d} \end{bmatrix} \tag{11}$$

In this case there are four zero restrictions and this implies that the system is over identified and we can then test whether this restriction can be rejected.

Finally, beginning with the above specification, we also consider the case where aggregate supply shocks are permitted to have a long-run impact on prices. If this view is deemed plausible, the result will be consistent with a supply-side driven deflation. The relevant restrictions are written:

$$\begin{bmatrix} \Delta P \\ \Delta Y \\ \Delta M \end{bmatrix} = \begin{bmatrix} c_{11}(1) & c_{12}(1) & 0 \\ 0 & c_{22}(1) & 0 \\ c_{31}(1) & c_{32}(1) & c_{33}(1) \end{bmatrix} \begin{bmatrix} \varepsilon_{ms} \\ \varepsilon_{s} \\ \varepsilon_{d} \end{bmatrix} \tag{12}$$

This system is also exactly identified.

If (11) is rejected then we are unable to formally discriminate between (10) and (12). In the case of (10) the deflation would be interpreted as a monetary phenomenon, while in the case of (12) the results are consistent with a supply side induced deflation. Therefore, in order to discriminate between the two hypotheses we first separately estimate the relevant VARs for a sub-sample beginning in 1995 when the behavior of inflation clearly changes (see Figure 1). If the results are similar across the two sub-samples then there is little evidence that the era of disinflation and deflation was driven by different shocks than ones explaining the period of rising inflation.

4. Empirical Results

4.1 Data

All models are estimated with quarterly data with the sample period 1990:1 to 2003:3. The data are collected from National Bureau of Statistics (NBS, formerly known as the State Statistics Bureau), the China Statistical Yearbook, the People's Bank of China website, and the International Financial Statistics CD-ROM. Because the statistical administration in China is still developing, only nominal GDP[7] was available on a quarterly series while CPI did not

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[7] Estimates of GDP are made independently from the production side (sum of value added) and the expenditure side (sum of final expenditures). Different estimates are obtained by the two methods. The NBS considers that its estimates from the production side are more reliable and the statistical discrepancy is therefore shown in the estimates of GDP from the expenditure side. The quarterly estimates of GDP from the production side distinguish 13 separate activities for the tertiary sector, but there is no breakdown of the primary sector (agriculture, animal husbandry, forestry and fishing) and the secondary sector is broken down into only

become an official economic indicator until 2000. No CPI index is published. Instead a measure of inflation, in percent at annual rates, is available only. Therefore, real output was estimated by deriving a price index from published inflation figures and dividing nominal GDP by the resulting price index. The year 1989 was taken as the base year.[8] Additional seasonal adjustment is performed to remove seasonality in real GDP levels and price index.[9] Next, the log first difference of the estimated quarterly real GDP figure is evaluated to obtain output growth. In addition, several proxies for the output gap, described earlier, were also considered. To determine the sensitivity of our results, we repeat all our estimations using industrial production. In the case of both output measures, we use a gap measure derived by relying on a proxy for potential output, as explained previously. The money stock is measured either using as narrow money and Quasi-money, using the IMF definitions. Additional explanations about the data and their sources are provided in the Appendix.

4.2 Estimates of Structural Shocks

Figures 5a and 5b plot the impulse response functions based on the standard BQ decomposition applied to (4) which is also equivalent to the condition whereby shifts in AS cause shifts in AD. Both full sample (top two figures; 1990-2003) and sub-sample (bottom two figures; 1995-2003) estimates are shown.[10] In the case of inflation AS shocks clearly dominate in the full sample while AD shocks are slightly more important in the disinflation/deflation sample. Turning to the impact of AD and AS shocks on output we find that whereas AD shocks temporarily reduce real GDP growth in either sample, AS shocks have a positive, albeit temporary impact on growth, again in both sample considered. Clearly, the response of inflation is sensitive to the chosen sample while the impact of shocks on output growth is relatively less sample sensitive. However, a look at Figure 5b reveals that the impact of AD and AS shocks is also sensitive to the choice of our measure of output. When a proxy for the gap in industrial production is used we now find that AD shocks are clearly the most important determinants of

"industry" and "construction". The discrepancies are not large and are about 1% of GDP on average. Quarterly GDP data are provided in Press Releases issued at regular press conferences held in April, July, October and January (Chinese). Source: IMF, general data dissemination system site, data category and indicators of China, from http://dsbb.imf.org/Applications/web/gdds/gddscountrycategorydcreport/?strcode=CHN&strcat=NGDP0.

[8] The official year-to-year change of consumer price is available from 1990 only.

[9] The ARIMA X-12 (additive) procedure was used to obtain seasonally adjusted estimates.

[10] It has been suggested to us that splitting the sample around 1997, to account for the Asian crisis, might be preferable. Doing so, however, would leave too few usable observations to perform the kind of econometrc testing envisaged here. Nevertheless, as our full and sub-sample estimates both confirm the central role played by monetary factors we can only presume that this result would also hold for a sub-sample since the Asian crisis (also see Burdekin and Siklos 2005).

inflation, regardless of the chosen sample. In the case of output responses to AD and AS shocks, both types of shocks have positive, but only temporary, effects on industrial production with AS shocks producing the largest impulse responses of the two. While the results are clearly mixed the notable aspect of these results is that there is considerable scope for interpreting China's inflation and output as possible being driven by AD shocks even when we permit shifts in AS to cause shifts in AD.

The case where AD shocks cause AS shocks is considered in Figure 6. The most significant result is that the impulse responses are no longer seen as sensitive to the output proxy. In particular, AD shocks impact inflation most in both samples using either measure of output. In the case of impulse responses for output AD and AS shocks both have temporary but positive effects on either output proxy. To the extent that consistency across output proxies makes for more convincing results, this suggests that inflation and deflation in China are more likely AD driven than exclusively, or even primarily, an AS phenomenon.

While impulse responses are useful, a more helpful perspective perhaps comes from an examination of variance decompositions (VD). Tables 3a and 3b present VDs for the full sample case only where real GDP growth is the output measure. Table 3a shows the standard AD-AS model (with the direction of the relationship running from AS to AD shocks) while Table 3b provides the case where AD shocks are assumed to cause AS shocks. In the standard model, variation in output is primarily explained by AS shocks, although AD shocks also play an important role. In the case of inflation, the standard model reveals that inflation overwhelmingly explained by aggregate supply shocks.

Turning to the case where the relationship runs from demand to supply gives an entirely different picture. Now, AD shocks explain almost all of the variation in output growth. Under this scenario, independent AS shocks cannot explain Chinese output growth. In the case of inflation, it is still the case that AS shocks explain much of the variation in inflation in the short-term. However, at longer horizons, AD shocks become relatively more important. The point estimates of the correlation between AD and AS shocks is 0.45 and this indicates that both AD and AS schedules shift together.[11]

The results so far do not provide information about separate impact of monetary policy. Figure 7, therefore, provides impulse response functions for the trivariate VAR with these

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[11] The estimate is slightly lower than the point estimate of 0,64 reported in Cover, Enders and Hueng (2005). Given the short span of the sample, one cannot claim that these point estimates are precisely estimated.

separate sets of restrictions considered. Since the results for 1995-2003 are similar only the full sample estimates are shown. Indeed, the similarities in the impulse responses over the two samples suggest that the disinflation and deflation era does not appear to be fundamentally different from the inflationary period that preceded it. As noted previously, the second set of restrictions, namely that AD shocks (that is, spending and monetary policy shocks) have no long-run effects, produces an over-identified model the validity of the restrictions can be tested. The likelihood ratio test statistic is 27.93 (.00). Consequently, the null is soundly rejected. This leaves two alternatives, namely, either that AS shocks are neutral or that monetary policy shocks are neutral while AS shocks are unconstrained in the long run. Impulse responses for the first case are shown at the top of Figure 7 while the responses for the second case are plotted at the bottom of the same Figure. When AS shocks have no long-run impact on inflation monetary policy is inflationary while AD and AS shocks are deflationary. Moreover, money growth responds strongly to monetary policy shocks and to AD shocks but not to AS shocks. Finally, output growth responds positively to monetary policy studies partially offsetting the negative response to AD while AS shocks have a temporary but positive impact on real GDP growth.

The situation is rather different when AS shocks are not restricted in the long-run, as shown at the bottom of Figure 7. Aggregate supply shocks now have a relatively larger impact on inflation than do money supply shocks while AD shocks have an offsetting negative impact on inflation. Similarly, monetary policy has a temporarily negative effect on output growth as do AD shocks while AS shocks generally stimulate output growth. Finally, monetary policy responds positively to all sources of shocks but especially to AS shocks. Recall that when monetary policy is not restricted to be neutral AS have no lasting impact on money growth.

Taken together, and given the earlier overview of the policy framework in China over the period considered, the case depicted at the top of Figure 7 or the alternative identification strategy suggested by Cover, Enders and Hueng (see Figure 6) appear to be the most plausible. These results suggest that while AS shocks were deflationary, money supply shocks ultimately explain the course of inflation in China since 1990. Regardless of the identification scheme aggregate demand shocks prove to be deflationary – a reflection perhaps of the impact of China's relatively high savings rate (e.g., see Watanabe 1998). Finally, as shown in Table 2, additional tests reveal that variables such as inflation in commodity prices are exogenous. Consequently, the addition of such variables did not affect the impulse responses shown in Figure 7. The same is generally true for export growth and for the growth in the nominal effective exchange rates although one is able to reject the null that the exchange rate is

exogenous in the inflation equation. Nevertheless, the impulse responses (now shown) are largely unaffected. Hence, monetary policy responses remain the principal determinant of inflation in China.

5. Conclusions

In light of the recent debate over the role of monetary policy and aggregate supply factors in explaining the recent Chinese deflationary experience, the starting point for this paper was to ask whether the monetary transmission process of the highly centralized economy can be adequately described by estimating structural VARs. For this purpose, different models were estimated for the full sample, and a sub-sample using Chinese data for the period from 1990 to 2004. The structural shocks were identified by a mixture of long run and short-run restrictions, following the Blanchard-Quah decomposition methodology, and two variants of this approach.

Money supply shocks largely explain inflation while aggregate supply shocks play a secondary role. Therefore, our results do not support the "supply-driven" view of China's deflation. The only way one can conclude that the Chinese deflation was driven by aggregate supply factors is by assuming that AS and AD shocks are uncorrelated, and this appears highly unlikely in the Chinese case.

The results also reveal how China was able to escape deflation. An aggressive loosening of monetary policy permitted the ending of deflation. However, the results also point to a role for AS factors. Further, the Chinese experience does suggest that deflation need not be of the bad variety. Nevertheless, since it is difficult to precisely identify the sources of AS shocks, the PBC should not automatically rely on future productivity improvements to prevent an excessively loose monetary policy from producing once again excessively high inflation.

Table 1. Summary Statistics for the Chinese Economy, 1990-2003

	Full sample	Inflation only	Disinflation-Deflation only
Real GDP	8.86	11.34	7.74
Industrial Production	14.82	22.03	12.10
Inflation	5.68	10.34	3.02
Output Gap (Real GDP)	-	-0.004	0.002
Output Gap (Industrial Production)	-	0.82	-0.317

Note: See appendix and Figures 1 to 3 for additional details. The output gap figures are based on the HP filtered measures of the output gap. The disinflation-deflation sample consists of data for the 1995-2003 period only.

Table 2. Tests of Exogeneity

Independent Variable	Test Statistic (p-value)			
	Commodity Price Inflation	Commodity Price Inflation Non Fuel	Export Growth	Nominal Effective Exchange Rate
Inflation	.75 (.86)	3.55 (.31)	2.74 (.43)	8.97 (.03)
Real GDP growth	.96 (.81)	4.40 (.22)	4.49 (.21)	3.42 (.33)
Money Supply growth	2.67 (.44)	1.35 (.72)	10.38 (.02)	5.90 (.18)

Note: Based on the three variable VAR described in the test estimated over the full sample. The test statistic is the χ^2 test for block exogeneity with p-values given in parenthesis.
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Table 3. Variance Decompositions: Full Sample

a. <u>Standard AD-AS Model (AS causes AD)</u>

	Output Growth		**Inflation**	
Horizon	*Due to AS*	*Due to AD*	*Due to AS*	*Due to AD*
1.000	0.524	0.476	0.761	0.239
2.000	0.507	0.493	0.790	0.210
3.000	0.535	0.465	0.788	0.212
4.000	0.654	0.346	0.800	0.200
5.000	0.613	0.387	0.827	0.173
6.000	0.585	0.415	0.818	0.182
7.000	0.585	0.415	0.826	0.174
8.000	0.597	0.403	0.829	0.171
9.000	0.595	0.405	0.832	0.168
10.000	0.596	0.404	0.832	0.168
11.000	0.597	0.403	0.833	0.167

b. <u>AD-AS Model (AD causes AS)</u>

Horizon	*Due to AS*	*Due to AD*	*Due to AS*	*Due to AD*
1.000	0.025	0.975	0.804	0.196
2.000	0.031	0.969	0.772	0.228
3.000	0.103	0.897	0.776	0.224
4.000	0.283	0.717	0.763	0.237
5.000	0.361	0.639	0.727	0.273
6.000	0.373	0.627	0.737	0.263
7.000	0.373	0.627	0.728	0.272
8.000	0.358	0.642	0.726	0.274
9.000	0.356	0.644	0.721	0.279
10.000	0.358	0.642	0.721	0.279
11.000	0.369	0.631	0.720	0.280

Notes: Output growth is the real GDP. Inflation is the rate of change in CPI. See Figures 1 and 2.

Inflation in China: 1990-2003


Inflation in the United States, 1960-2002
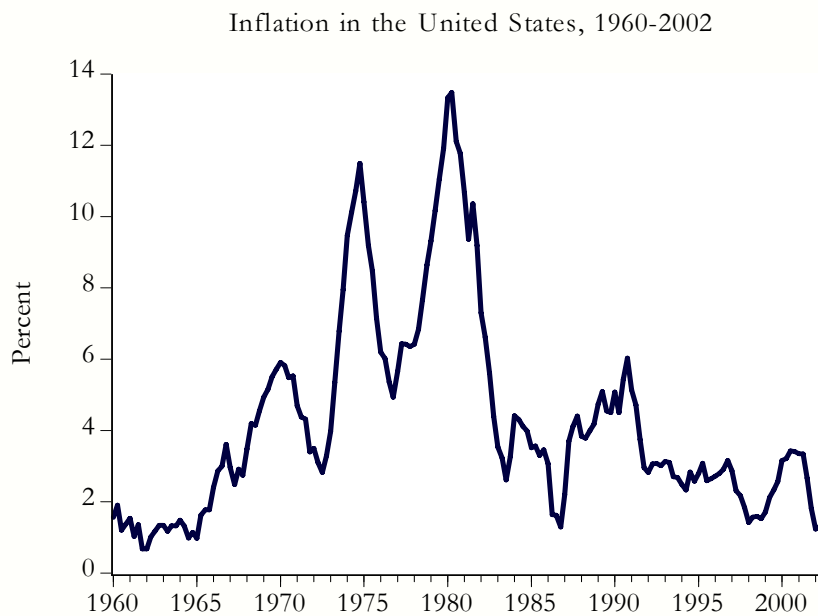
Note: Inflation in China is the log change in the CPI. See the appendix. Inflation in the US is the annual rate of change (fourth order log difference) in the US CPI. Data from FRED II (research.stlouisfed.org/fred2/).

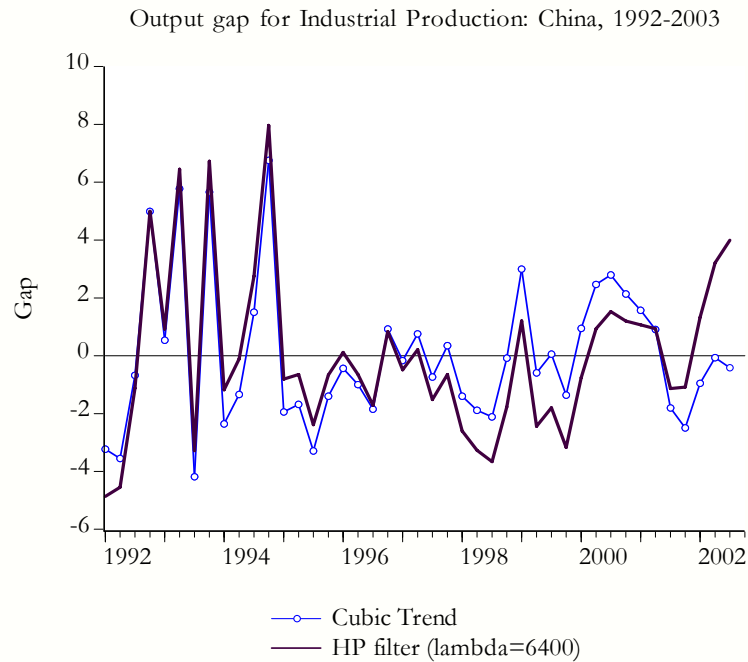**Figure 1   Comparing China's and the US's Inflation Rate**
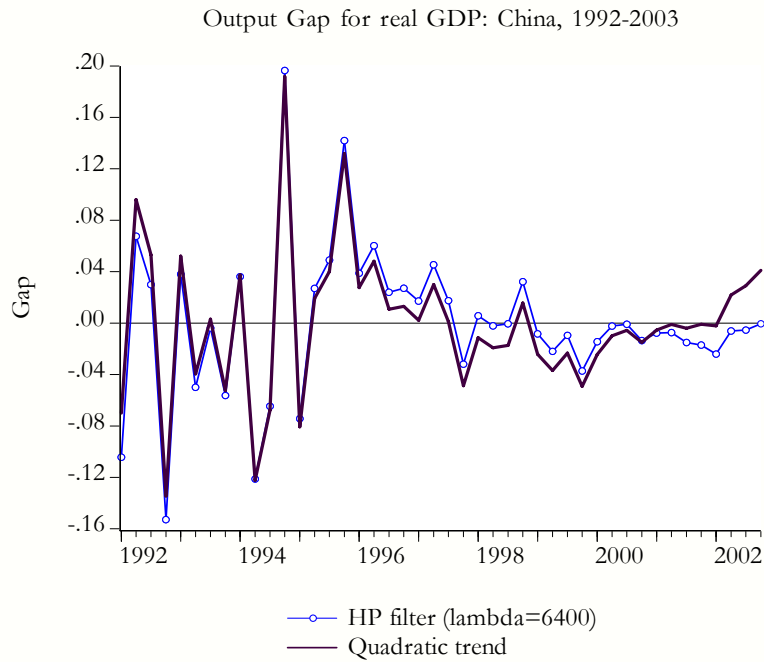
Figure 2 Alternative Estimates of Output Growth in China

China: Growth in real GDP and Industrial Production, 1990-2003
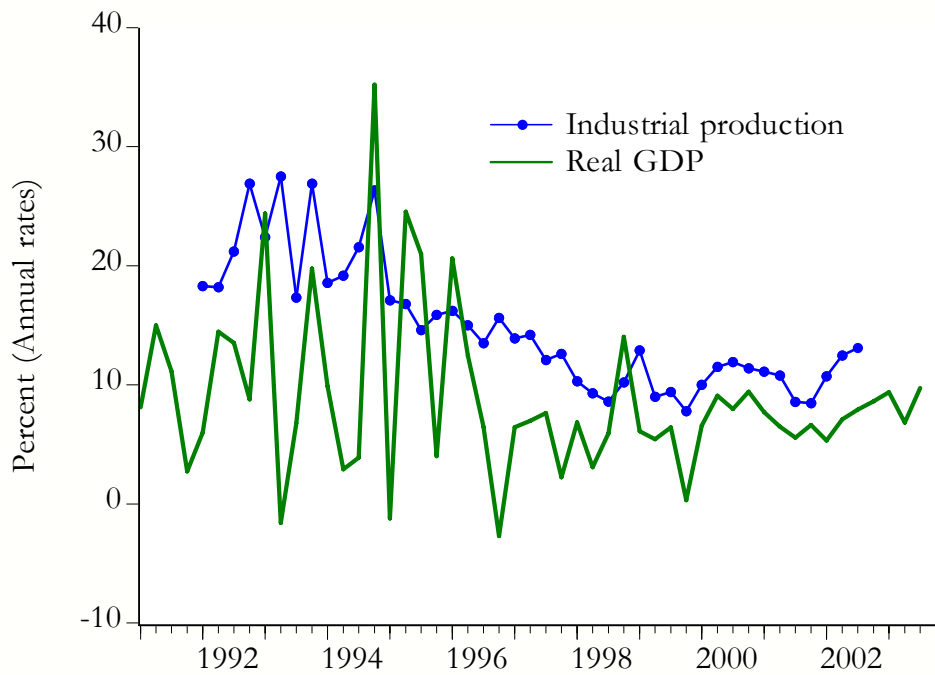
Note: Real GDP growth is the annual rate of change in the seasonally adjusted real GDP (fourth order log difference). Seasonal adjustment was obtained using X11 (additive method). Industrial production growth is from the IFS CD-ROM (IMF: Washington, D.C.).

Figure 3 Proxies for the Output Gap

Output Gap for real GDP: China, 1992-2003

HP filter (lambda=6400)
Quadratic trend

Output gap for Industrial Production: China, 1992-2003

Cubic Trend
HP filter (lambda=6400)

Note: The output gap is log of real GDP or Industrial Production less the HP filtered value (with smoothing parameter shown above) or from the fitted values of either a quadratic or a cubic trend fitted to the log levels of either series.

Figure 4 Monetary Variables for China
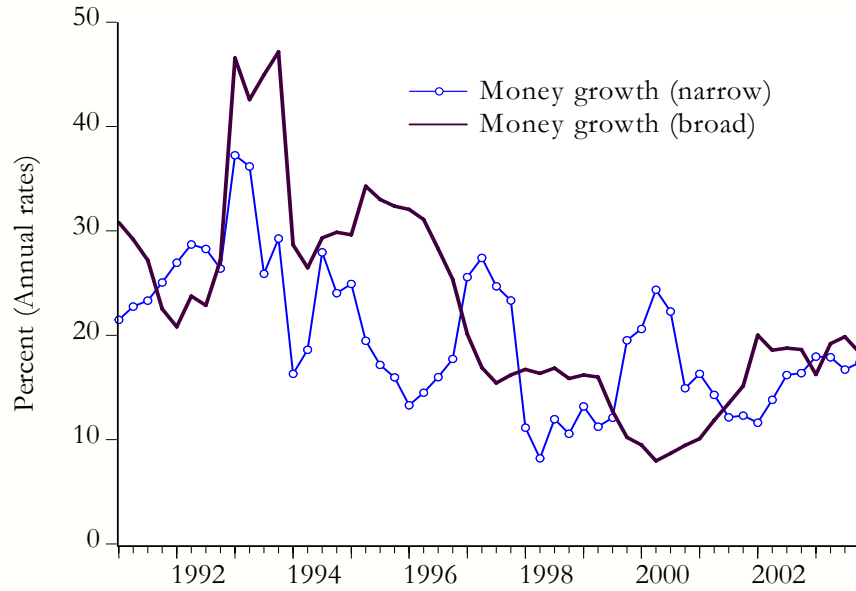
The PBC's benchmark interest rate, 1991-2003
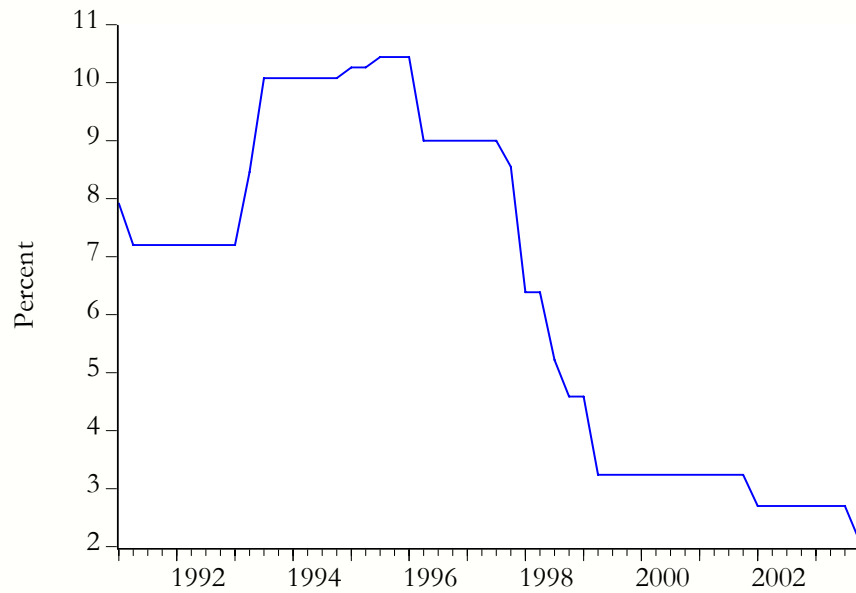
Note: For data sources, see the appendix. Annual growth rates for narrow and broad money are plotted.

Figure 5a Impulse Response Functions: BQ Decomposition

BQ Decomposition: Full Sample, 1990-2003

Response of Inflation
to Structural One S.D. Innovations

Response of real GDP growth
to Structural One S.D. Innovations

—— AD shock --•-- AS shock

—— AD shock --•-- AS shock

Response of Inflation
to Structural One S.D. Innovations

Response of real GDP growth
to Structural One S.D. Innovations

—— AD shock --•-- AS shock

—— AD shock --•-- AS shock

BQ Decomposition: Sub-sample, 1995-2003
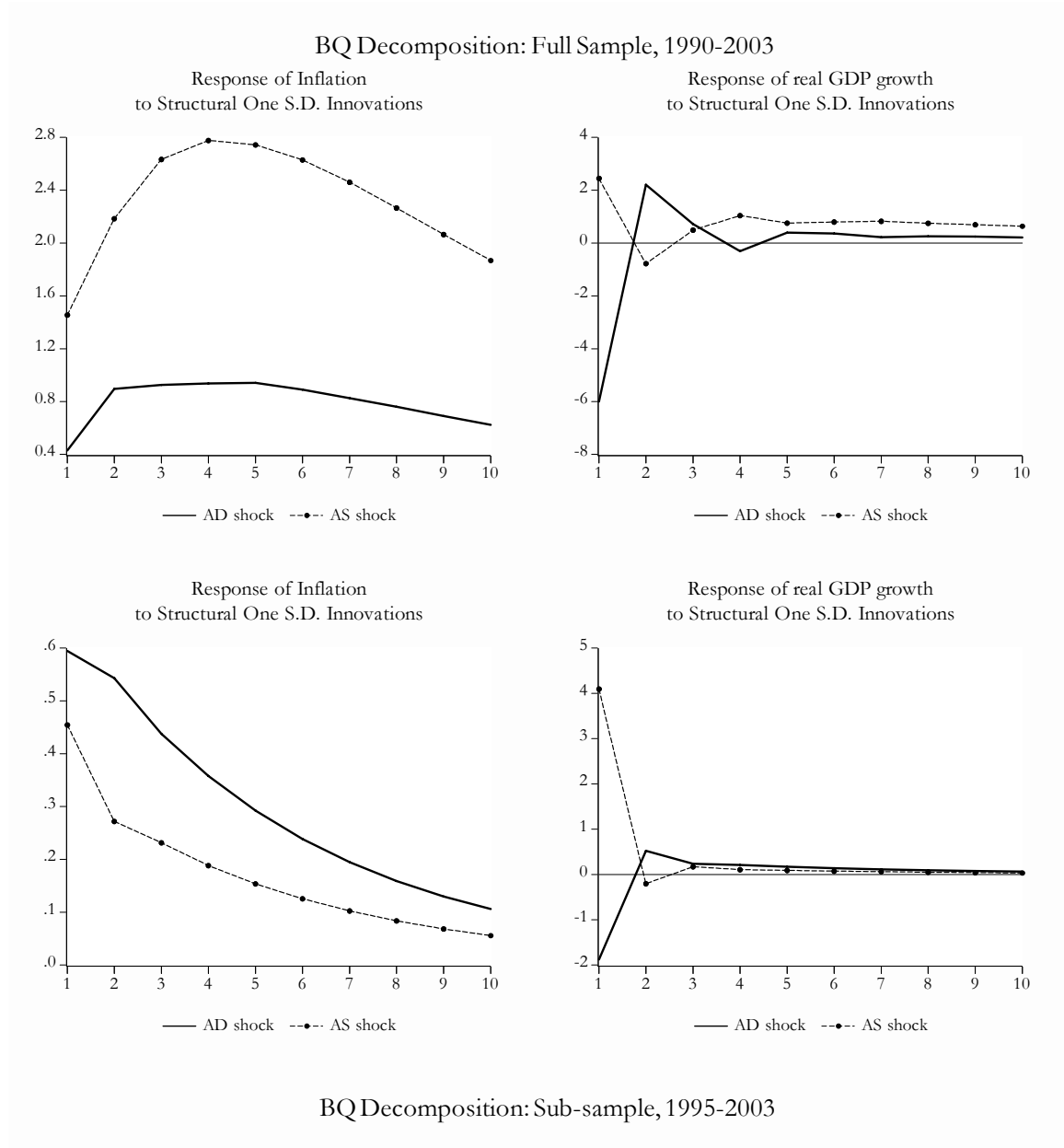
Note: For estimation details, see text.

Figure 5b Impulse Response Functions: BQ Decomposition

BQ Decomposition: Full Sample, 1990-2003

Response of Inflation
to Structural One S.D. Innovations

Response of Industrial Production
to Structural One S.D. Innovations

Response of Inflation
to Structural One S.D. Innovations

Response of Industrial Production
to Structural One S.D. Innovations

BQ Decomposition: Sub-sample, 1995-2003
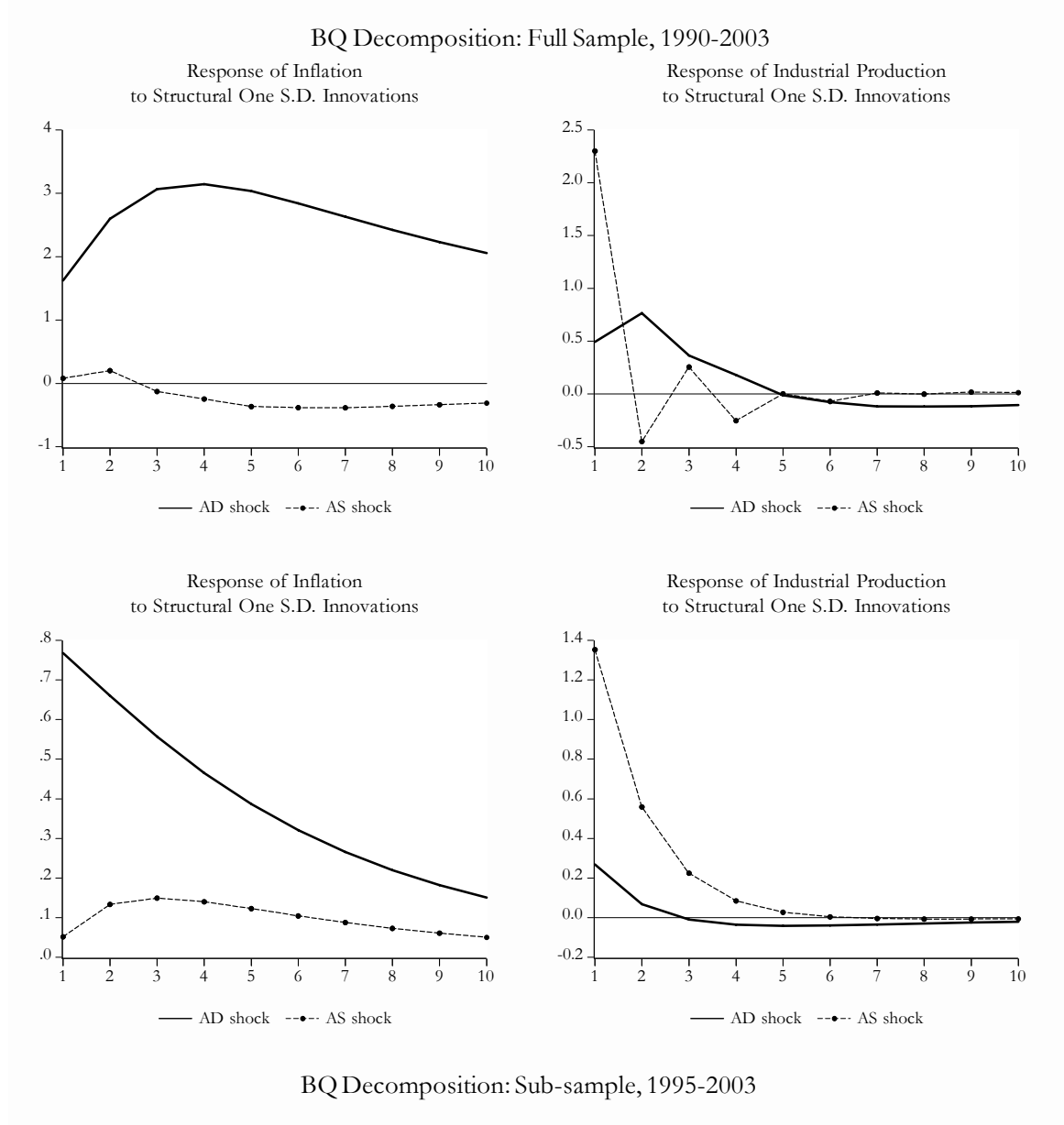
Note: For estimation details see text.

Figure 6a Impulse Response Functions: Alternative Identification Assumption

BQ Decomposition Using Alternative Identification Strategy
Full Sample, 1990-2003

Response of Inflation
to Structural One S.D. Innovations

Response of real GDP growth
to Structural One S.D. Innovations

Response of Inflation to Structural
One S.D. Innovations

Response of real GDP growth
to Structural One S.D. Innovations

BQ Decomposition Using Alternative Identification Strategy
Sub-sample, 1995-2003
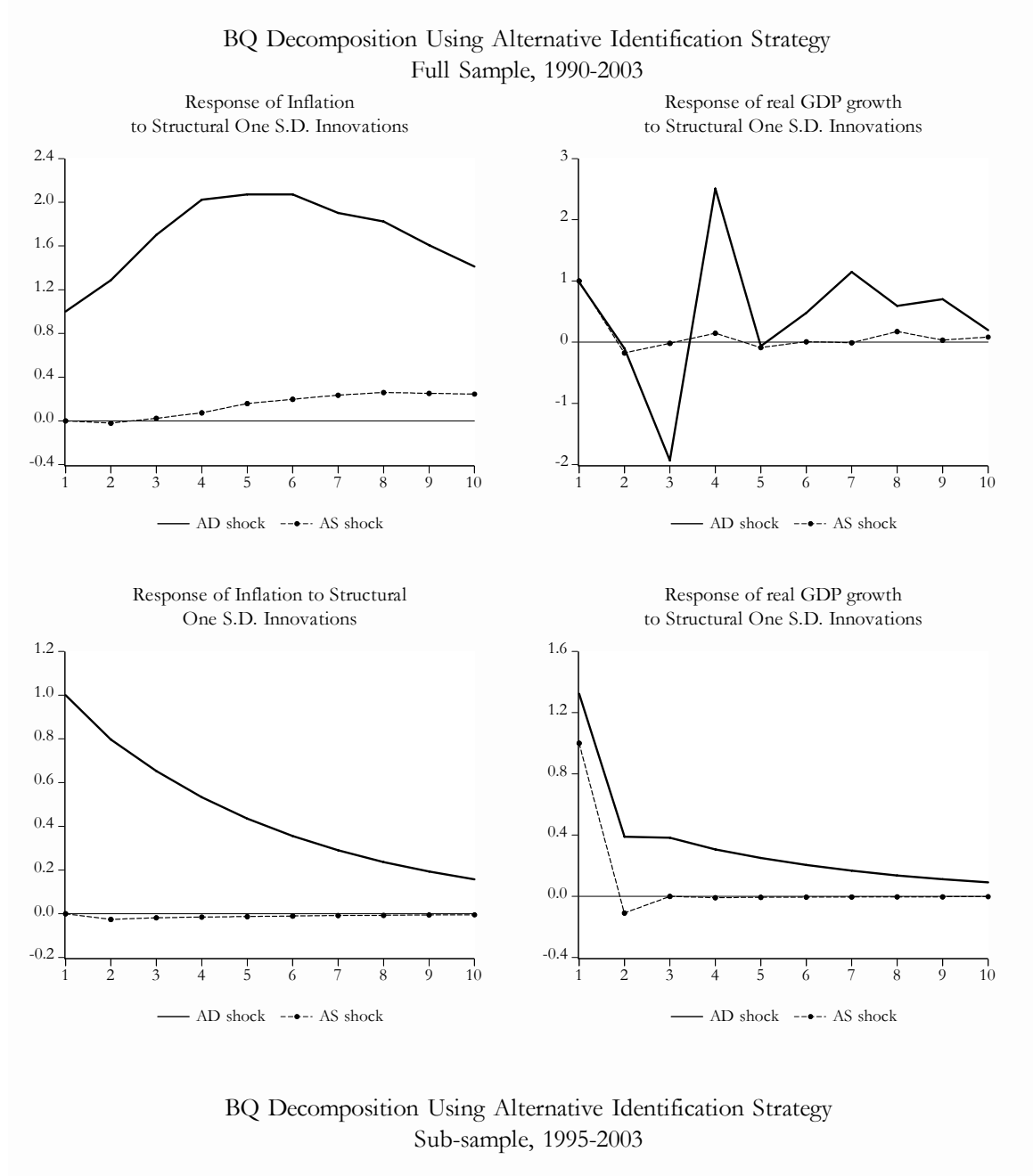
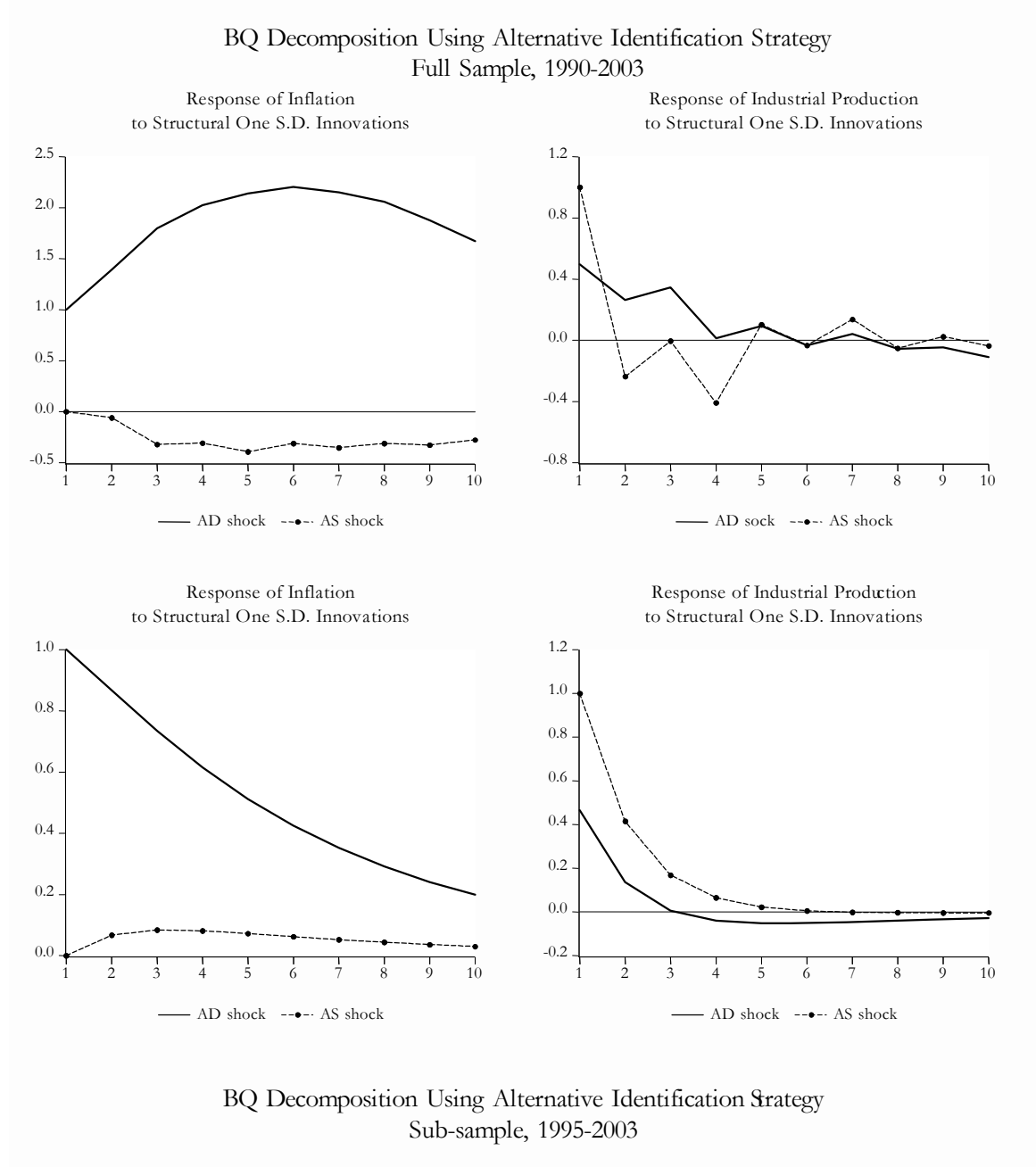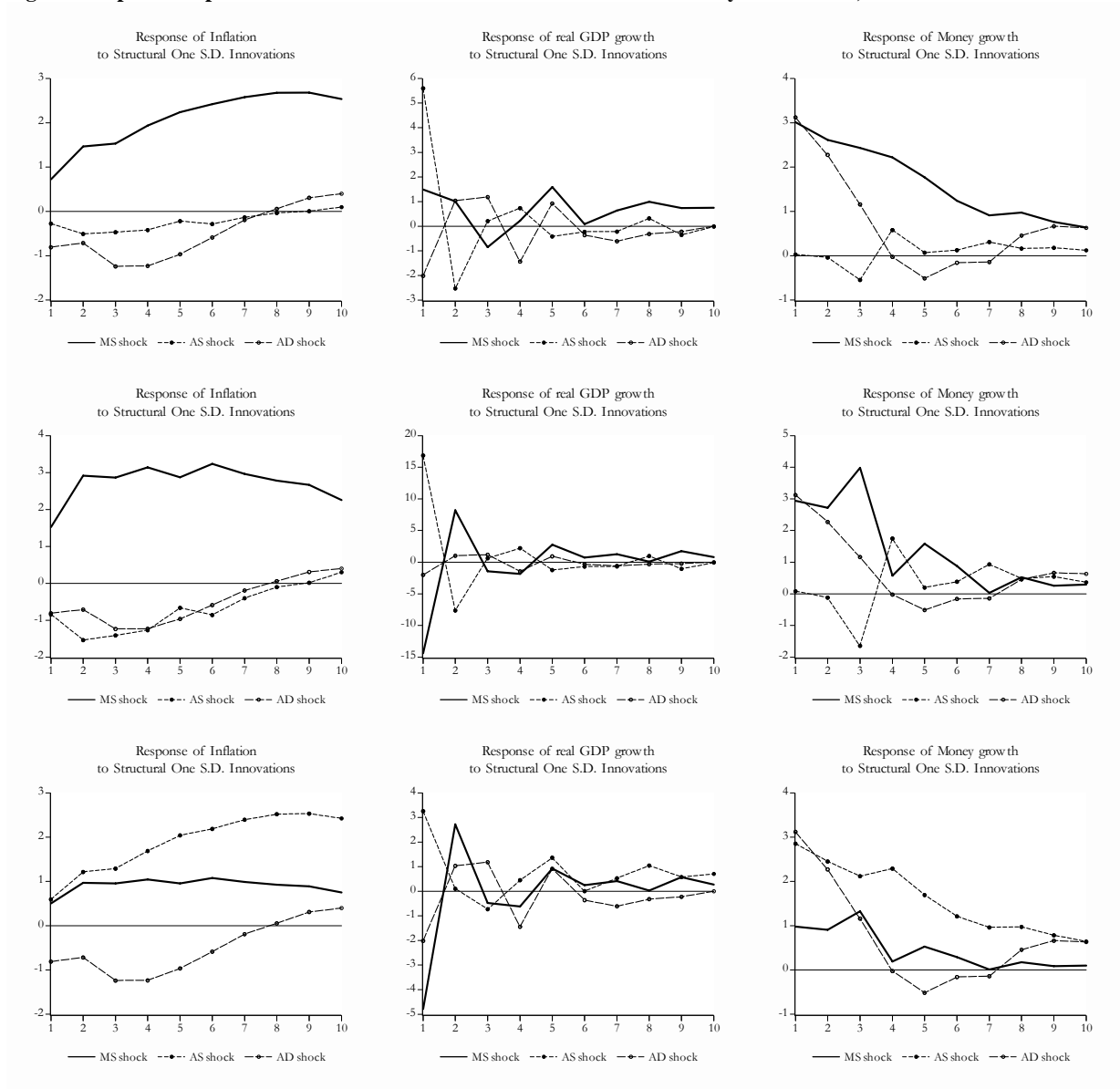**Note:** For estimation details, see text.

Figure 6b Impulse Response Functions: Alternative Identification Assumption

BQ Decomposition Using Alternative Identification Strategy
Full Sample, 1990-2003

Response of Inflation
to Structural One S.D. Innovations

Response of Industrial Production
to Structural One S.D. Innovations

—— AD shock --•-- AS shock

—— AD sock --•-- AS shock

Response of Inflation
to Structural One S.D. Innovations

Response of Industrial Production
to Structural One S.D. Innovations

—— AD shock --•-- AS shock

—— AD shock --•-- AS shock

BQ Decomposition Using Alternative Identification Strategy
Sub-sample, 1995-2003

Note: For estimation details, see text.

Figure 7 Impulse Response Functions: Trivariate VAR with Alternative Policy Restrictions, 1990-2003

Note: For estimation details, see text.

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Appendix

CPI calculation: Before 2000, there was no economic indicator of Consumer Price Index in China and the available official index for price level measure from 1985 to 2000 is annual or monthly change of consumer price. Year 2000 was made as the base period of the first round of compile fix-based monthly price index (Year 2000=100).

(1)   Grouping of CPI. The consumer price index in China consists of 8 major categories: food, alcoholic beverages and tobacco products, clothing, household equipment and service, health and personal care, transportation and communication, entertainment, education and culture, shelter, etc.

(2)   Selection of representative items. In the previous series, 289 kinds of goods and 36 kings of services have been selected for China's CPI. The current CPI is based on a basket comprised of 500-600 goods and services, which are aggregated into 282 subgroup, then into 80 groups and finally into 8 sections. Those goods and services were guided by certain criteria and based on the accounting material of about 30,000 urban households and 60,000 rural households.

(3)   Selection of surveying area and outlets. There are about citied and countries used for China CPI survey up to now. In each area, shops (including country fairs and service sites)are selected based on their sales volume and abundance of goods, and they must be representative of price trends. There are nearly 10000 outlets included in China CPI.

(4)   Price collection. Prices are collected directly by professional staff at certain time and outlets, which are: (a) Those actually paid by purchasers rather than the amounts listed in the counter.(b) Items have close relation to people's life and their prices change frequently are priced at least every five days; Others are collected 2-3 times each month; where prices are controlled by government or price movement are relatively stable, information is collected monthly or quarterly.

(5)   Source of the weights. The weights of CPI are calculated according to the expenditure structure in household survey annually, while weights for fresh vegetables and foods are adjusted monthly.

(6)   Release of the Index. Index is released through monthly economic reports of NBS on 12th of following month and quarterly news release conference of NBS.

GDP calculation: GDP in China is the sum of the gross value added by all resident producers in the economy plus any taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Transfer payments are excluded from the calculation of GDP. Value added is the net output of an industry after adding up all outputs and subtracting intermediate inputs. The industrial origin of value added is determined by the International Standard Industrial Classification (ISIC) revision.

Data source description: NBS is the abbreviation of National Bureau of Statistics of China. Its responsibility include: Drafting and implementing statistics and regulations; Overseeing statistical and national accounting activities of local governments and ministries.Improving the systems of national accounts and statistical indicators;formulating the national statistical standards; Collecting national statistics and conducting statistical analysis of economic, social, and technological development; Improving the automated statistical information system and the national statistical database.

It was set up in 1952 and until March 1999 the NBS launched the China Statistical Information Network (**www.stats.gov.cn**), an online resource that makes information from NBS databases available to a wider audience, including detailed statistics on economic and social development, information from various censuses and the NBS's monthly statistics on national economic performance. The statistical data before 1999 is only available from the annual publication of NBS, the China Statistical Yearbook.

China Statistical Yearbook: It is an annual statistics publication, which covers very comprehensive data in every year and some selected data series in historically important years and the most recent twenty years at national level and local levels of province, autonomous region, and municipalities directly under control of the central government and therefore, reflects various aspects of China's social and economic development.