Exploring the international transmission of U.S. stock price movements

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19 May 2010

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Abstract

I investigate the transmission of U.S. stock price shocks to real activity and prices in G-7 countries using a multicountry vector autoregressive (VAR) model. I achieve identification by imposing a small number of sign restrictions on impulse responses, while controlling for monetary policy, business cycle and government spending shocks. The results suggest that (a) stock price movements are important for fluctuations in G-7 real activity and prices but do not qualify as demand side business cycle shocks and (b) the transmission is similar across G-7 countries.

Keywords: international transmission, stock prices, G-7 countries, multicountry VAR, identification with sign restrictions

JEL-Codes: C33, E44, F30

*I am grateful to Stefan Gerlach, Peter Tillmann, and the participants of the DIW Macroeconometric Workshop in Berlin 2009 and the RGS Doctoral Conference in Economics in Bochum 2010 for helpful comments. Contact information: Tim Oliver Berg, Institute for Monetary and Financial Stability (IMFS), Goethe University Frankfurt, Grüneburgplatz 1 (Box H12), 60629 Frankfurt am Main, Germany, Tel.: +49 (0) 69 798 34503, Fax: +49 (0) 69 798 34502, email: tberg@wiwi.uni-frankfurt.de

1 Introduction

There is an increasing number of VAR-based studies that stress the role of stock prices in explaining macroeconomic developments. For example, Beaudry and Portier (2006) argue that shocks to stock prices reflect changes in agents' expectations about future total factor productivity which is in turn an important driver of U.S. business cycles. Fratzscher et al. (2007) point to stock market wealth as an explanation for U.S. external imbalances, while in an extension to the G-7 countries, Fratzscher and Straub (2009) find that shocks to stock returns have sizeable effects on external accounts. Furthermore, Assenmacher-Wesche and Gerlach (2008) study the relationship between stock prices, real activity and prices in industrialized countries and find a significant transmission of stock price shocks.

The main challenge in identifying stock price shocks is to disentangle movements in stock prices that are due to the business cycle or to other shocks and those that are exogenous, a difficulty the existing literature largely ignores. One camp uses sign restrictions on impulse responses and treats shocks to stock prices as demand side business cycle shocks, assuming that stock prices impact on real actvity and prices (see, e.g., Fratzscher et al., 2007; Fratzscher and Straub, 2009). Another camp imposes zero restrictions on impulse matrices and rules out a contemporaneous effect of stock prices on real actvity, prices and interest rates (see, e.g., Assenmacher-Wesche and Gerlach, 2008). Both approaches are debatable. The first one is dogmatic regarding the nature of stock price shocks, the second imposes short-run restrictions that are likely to be violated in reality. A counterexample is the immediate monetary policy response to the stock market crash in October 1987.

In this paper, I identify shocks to U.S. stock prices using a small number of sign restrictions on impulse responses, while controlling for monetary policy, business cycle and government spending shocks. The approach allows me to filter out the effects of these shocks on stock prices and is agnostic with respect to the nature of stock price shocks. The procedure shares similarities with the identification scheme of Mountford and Uhlig (2005) in the context of fiscal policy shocks. Furthermore, consistent with the aforementioned studies, I take an international perspective. I use a multicountry VAR for the G-7 countries as described in Canova and Ciccarelli (2009). The approach is novel and has been used so far to construct indicators of world and national business cycles (see Canova et al., 2007) or to investigate the propagation of monetary and technology shocks between the U.S. and the euro area (see Caivano, 2006). I prefer the multicountry VAR to other panel data approaches since it allows for cross-country lagged interdependencies and heterogeneous dynamics. Both features are often neglected in the literature but likely to be present in my context. Furthermore, the multicountry VAR methodology can be applied to panel data where the cross-sectional dimension is short and the time series is of moderate length only. In addition, a factor structure keeps estimation simple.

I find that stock price shocks are important for fluctuations in G-7 real activity and prices even when controlling for other shocks. However, such shocks do not qualify as demand side business cycle shocks since they do not induce a positive comovement of real activity and prices. Moreover, the transmission appears to be similar across G-7 countries.

The rest of the paper is organized as follows. Section 2 outlines the multicountry VAR and the identification strategy with sign restrictions. Section 3 describes the empirical implementation. In Section 4, I discuss the preferred specification of the multicountry VAR and document its empirical properties. Section 5 presents an impulse responses analysis. Section 6 presents a forecast error variance decomposition. Finally, Section 7 concludes.

2 The multicountry VAR and identification

2.1 The model

Consider the multicountry VAR:

$$y_{it} = \sum_{j=1}^{p} B_{ij} Y_{t-j} + c_i + u_{it}, \tag{1}$$

where $i = 1, 2, ..., N$; $t = 1, 2, ..., T$; y_{it} is a $G \times 1$ vector of variables for country i, B_{ij} is a $G \times NG$ coefficient matrix for lag j, $Y_t = (y'_{1t}, y'_{2t}, ..., y'_{Nt})'$ is a $NG \times 1$ vector containing the variables for all N countries, c_i is a constant, and u_{it} is a $G \times 1$ vector of random disturbances.

Grouping coefficients for country i yields a $NGp + 1 \times G$ matrix $\delta_i = (B_{i1}, B_{i2}, ..., B_{ip}, c_i)'$. Furthermore, let $\delta = vec(\delta_1, \delta_2, ..., \delta_N)$ be the $NGk \times 1$ vector of all coefficients, where $k = NGp + 1$ is the number of coefficients in each equation. In most applications, k is larger than the number of observations T and the multicountry VAR cannot be estimated without imposing restrictions. I follow Canova and Ciccarelli (2009) and assume that the coefficient vector can be factored as

$$\delta = \sum_{f=1}^{F} \Xi_f \theta_f, \tag{2}$$

where $F << k$ is the number of factors, the Ξ_f's are conformable matrices and the θ_f's are factor loadings. Thus the dimensionality is reduced significantly. Rather than a large number of coefficients, only a small number of factor loadings has to be estimated. The choice of the factors is application and sample dependent. Factors may cover variations that are common across countries and variables or are specific to a particular country, variable or lag. In contrast to Canova and Ciccarelli (2009), I do not let the θ's vary over time or allow for idiosyncratic components.

Let $X_{it} = \left(Y'_{t-1}, Y'_{t-2}, ..., Y'_{t-p}, 1\right)'$ be the $k \times 1$ matrix of regressors for country i and define $X_t = I_{NG} \otimes X'_{it}$, $\Xi = (\Xi_1, \Xi_2, ..., \Xi_F)$ and $\theta = (\theta'_1, \theta'_2, ..., \theta'_F)'$. The multicountry VAR can be rewritten as

$$\begin{aligned} Y_t &= X_t\delta + u_t \\ &= X_t\Xi\theta + u_t \\ &= \chi_t\theta + u_t, \end{aligned} \tag{3}$$

where $\chi_t = X_t\Xi$ and $u_t = (u'_{1t}, u'_{2t}, ..., u'_{Nt})'$.

For illustration, I consider $N = G = 2$, $p = 1$ and $F = 3$. Then $\Xi = (\Xi_1, \Xi_2, \Xi_3)$ and $\theta = (\theta_1, \theta'_2, \theta'_3)'$. Here θ_1 is a scalar (a common factor), $\theta_2 = (\theta_{21}, \theta_{22})'$ is a 2×1 vector of country specific factors and $\theta_3 = (\theta_{31}, \theta_{32})$ is a 2×1 vector of variable specific factors. Let $i_1 = (1,1,1,1,0)'$, $i_2 = (1,1,0,0,0)'$, $i_3 = (0,0,1,1,0)'$, $i_4 = (1,0,1,0,0)'$ and $i_5 = (0,1,0,1,0)'$, then

$$\Xi_1 = \begin{pmatrix} i_1 \\ i_1 \\ i_1 \\ i_1 \end{pmatrix}_{20\times1}, \quad \Xi_2 = \begin{pmatrix} i_2 & i_3 \\ i_2 & i_3 \\ i_2 & i_3 \\ i_2 & i_3 \end{pmatrix}_{20\times2}, \quad \Xi_3 = \begin{pmatrix} i_4 & i_5 \\ i_4 & i_5 \\ i_4 & i_5 \\ i_4 & i_5 \end{pmatrix}_{20\times2}, \tag{4}$$

implying that the first equation of the reparametrized multicountry VAR reads as

$$y_{11,t} = \theta_1\chi_{1t} + \theta_{21}\chi_{2t} + \theta_{22}\chi_{3t} + \theta_{31}\chi_{4t} + \theta_{32}\chi_{5t} + u_{11,t}, \tag{5}$$

where $\chi_{1t} = \sum_i \sum_g \sum_j y_{ig,t-j} + 1$, $\chi_{2t} = \sum_g \sum_j y_{1g,t-j}$, $\chi_{3t} = \sum_g \sum_j y_{2g,t-j}$, $\chi_{4t} = \sum_i \sum_j y_{i1,t-j}$ and $\chi_{5t} = \sum_i \sum_j y_{i2,t-j}$.

The overparametrized multicountry VAR is transformed into a parsimonious seemingly unrelated regression (SUR) model with observable linear combinations of the right hand side variables of the VAR as regressors. χ_{1t} contains information for all countries and variables, χ_2 (χ_3) contains information specific to country 1 (2) and χ_4 (χ_5) contains information specific to variable 1 (2). Pooling data in such a way removes both cross-section and time series noise and is expected to lead to more stable estimates of δ. Moreover, I allow the θ's to be different across equations and estimate the SUR model sequentially by ordinary least squares (OLS). Finally, I use the estimated factor loadings to recover the coefficient vector δ.

2.2 Implementing sign restrictions

Given the dimensionality of the model, an exact identification is not possible. But I can identify a subset of shocks for the U.S. and study their transmission. Suppose the U.S. is ordered first and the reduced form errors are expressed as linear combinations of the shocks: $u_{1t} = P_1\epsilon_{1t}$, with P_1 being a $G \times G$ matrix and ϵ_{1t} a $G \times 1$ vector of orthogonal shocks with covariance matrix $\Sigma_{\epsilon_1} = E\left(\epsilon_{1t}\epsilon_{1t}'\right) = I_G$. The model for the U.S. is thus given by

$$y_{1t} = \sum_{j=1}^{p} B_{1j}Y_{t-j} + c_1 + P_1\epsilon_{1t}. \tag{6}$$

The restriction on P_1 so far is: $\Sigma_{u_1} = E\left(u_{1t}u_{1t}'\right) = E\left(P_1\epsilon_{1t}\epsilon_{1t}'P_1'\right) = P_1\Sigma_{\epsilon_1}P_1' = P_1P_1'$. In order to achieve exact identification within the U.S. model $\frac{G(G-1)}{2}$ additional restrictions have to be imposed on P_1. A frequently used strategy is to assume a recursive ordering of the variables in y_{1t}, thus demanding P_1 to be lower triangular. This can be achieved by means of a Cholesky decomposition of Σ_{u_1}.

I follow a different approach and identify shocks by imposing restrictions on the sign of impulse responses. This approach is developed inter alia by Faust (1998), Canova and De Nicoló (2002), Uhlig (2005) and Rubio-Ramírez et al. (2005) and is motivated as follows. Suppose there does exist an orthonormal $G \times G$ matrix Q such that $QQ' = Q'Q = I$. Then $u_{1t} = P_1QQ'\epsilon_{1t}$ is an admissible decomposition and $\epsilon_{1t}^\star = Q'\epsilon_{1t}$ is a new set of shocks with the property that $\Sigma_{\epsilon_1^\star} = E\left(\epsilon_{1t}^\star\epsilon_{1t}^{\star\prime}\right) = E\left(Q'\epsilon_{1t}\epsilon_{1t}'Q\right) = I$. Thus, $\epsilon_{1t}^\star$ has the same covariance matrix as ϵ_{1t} but is associated with a different impulse matrix $P_1^\star = P_1Q$. This ability to create a large number of candidate impulses makes the sign restriction approach advantageous compared to recursive identification schemes. In recursive systems the number of possible factorizations is quickly exhausted and the factorization that produces responses that are consistent with a priori beliefs is chosen. But in many cases counterintuitive results cannot be avoided. The 'price puzzle' is an example. However, the sign restrictions approach allows me to consider a large number of decompositions and to avoid counterintuitive results. And instead of imposing informal short-run restrictions, I explicitly state which retrictions I use.

I apply the following algorithm. First, I calculate a lower triangular factor of Σ_{u_1}, labeled P_1, using a Cholesky decomposition. The results, however, are invariant to the ordering of the variables as Uhlig (2005) shows. The Cholesky decomposition is only a computational tool and

I could alternatively use an eigenvalue-eigenvector decomposition of Σ_{u_1}. Second, I draw a $G \times G$ random matrix W from a multivariate standard normal distribution and apply the QR decomposition to W, such that $W = QR$ and $QQ' = Q'Q = I$. Rubio-Ramírez et al. (2005) show that this Q matrix has the required uniform distribution. Third, I construct an impulse matrix $P_1 Q$ and calculate the associated responses. If all the restrictions are fulfilled, I keep the draw. Otherwise, I discard it. I consider a large number of candidate Q's and draw inference from those draws that are kept.

This strategy allows me to identify up to G shocks for the United States. Moreover, I let the remaining variables react according to a transformed covariance matrix. I transform $\Sigma_u = E(u_t u_t')$ in such a way that the identification of U.S. shocks is invariant to the ordering of the countries and variables in the model. Dees et al. (2007) apply a similar transformation in the context of a Global VAR. I provide details in Appendix A.

3 The empirical setup

I estimate the multicountry VAR on quarterly data for the years 1974-2005, covering a period of largely flexible exchange rates and rising financial globalization. The estimation period is limited by the availability of fiscal data. I provide a summary of the data sources in Appendix B. I include nine variables for each of the G-7 countries: the government budget (primary balance in percent of GDP), real government spending (real government consumption plus investment), real GDP, real private consumption, real private investment, the GDP deflator, a nominal short-term interest rate, a monetary aggregate, and nominal stock prices. I consider the government budget and real government spending to identify government spending shocks, while I use interest rates and monetary aggregates to identify monetary policy shocks. Moreover, real GDP, real private consumption, real private investment, the GDP deflator and nominal stock prices are the variables of interest.

Government budget outcomes and interest rates enter the model in levels, but I consider the remaining variables in annualized quarterly growth rates even though this may result in a slight misspecification of the model since I cannot exploit the informational content of cointegrating relationships in this case. But I want to ensure that all variables are expressed in the same unit of measurement, i.e. in percent, and that their variability is comparable before I construct averages. Otherwise averages could be dominated by a particular variable. Therefore I normalize all series by substracting the mean and by dividing by their respective standard deviation. Finally, I set the lag length to two. Since in the SUR model, regressors are averages over the lags of the variables, the results are robust to variations in the lag length.

Table 1: Sign restrictions on impulse responses

	Contractionary shocks to			
	U.S. Mon. Policy	U.S. Business Cycle	U.S. Stock Prices	U.S. Gov. Spend.
Gov. Budget		$-$		$+$
Gov. Spend.				$-$
GDP		$-$		
Consumption		$-$		
Investment		$-$		
GDP Deflator	$-$			
Money (M1)	$-$			
Interest Rate	$+$			
Stock Prices			$-$	

Notes: The horizon is four quarters.

Table 1 summarizes the sign restrictions. I impose restrictions for four quarters on the level of U.S. variables. I consider a horizon of one year to avoid only transitory movements in variables and thus spurious identification of shocks. Moreover, the horizon is consistent with related studies (see, e.g. Mountford and Uhlig, 2005; Scholl and Uhlig, 2008; Peersman and Straub, 2009, among others). Furthermore, I require that all the restrictions are satisfied simultaneously. This ensures orthogonality of shocks and allows me to filter out the effects of monetary policy, business cycle and government spending shocks on stock prices.

Monetary policy shocks raise interest rates, while monetary aggregates and the GDP deflator fall. Hence I avoid 'price or liquidity puzzles' by construction. Contractionary business cycle shocks depress real GDP, real private consumption and real private investment. I impose no restriction on the response of the GDP deflator and thus control for both supply and demand side shocks. But I require that the government budget deteriorates in response to contractionary business cycle shocks since important budget components, such as tax revenues or transfer payments, are influenced by the state of the economy. Shocks to stock prices contract stock prices, while I do not restrict the response of any other variable. Thus I am agnostic about the nature of such shocks. This distincts the approach from those in the related literature. I test the hypothesis that stock price shocks impact on real activity and the GDP deflator rather than assuming it. Finally, government spending shocks lower government spending and improve the government budget, assuming that the fiscal authority does not fully compensate for the reduction in spending by lowering taxes or increasing transfer payments.

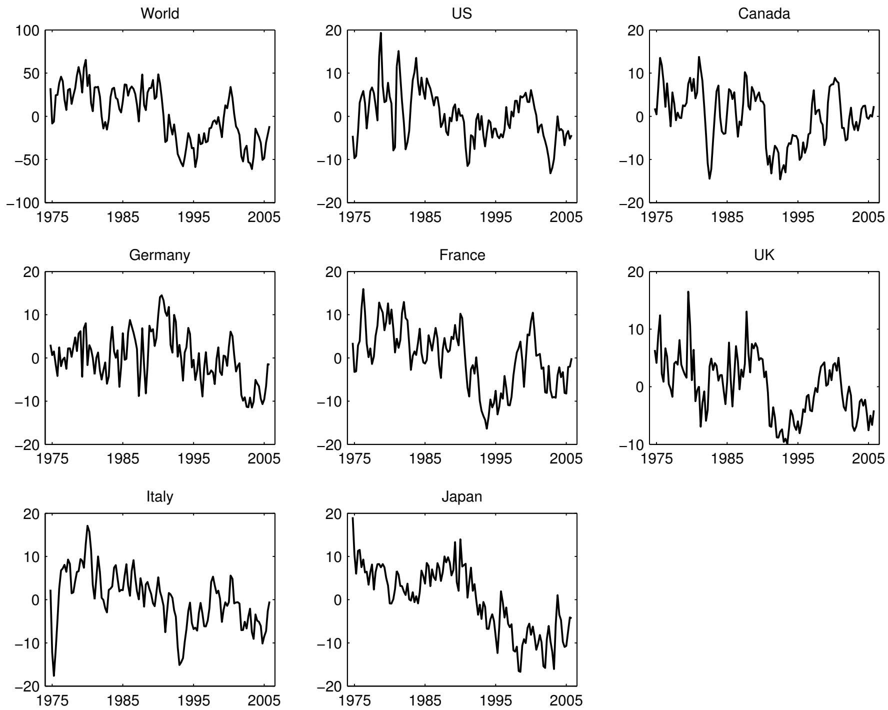

Figure 1: World and country indicators

4 International comovements of the variables

Before presenting impulse responses and a forecast error variance decomposition in the next two sections, I explore the country and variable-specific factor or indicator series. Given that the multicountry VAR methodology is novel and only few applications are available, it seems appropriate to check for its plausibility. Moreover, I want to investigate whether all the indicator series are necessary to model the data. Since the series are correlated by construction, it seems likely that I can leave out some when estimating the model.

Figure 1 shows the world and country indicators. The country indicators average across variables and lags and mirror important episodes for the countries under study. For example, the troughs in the U.S. indicator series coincide with the recessions that hit the U.S. during the sample period: one in the mid 1970s, the double dip recession in the early 1980s, the recession in 1991, and finally that of 2001. Moreover, the peak in the German indicator in the early 1990s marks the reunification boom, while the collapse of the European Monetary System (EMS) in 1992 is particularly evident for the UK and Italy. Furthermore, the weak economic performance in Japan during the 1990s which was accompanied by deflationary pressures results in a substantial decline of the indicator over this period.

Table 2: Correlation between the world and country indicators

	World	U.S.	Canada	Germany	France	UK	Italy	Japan
World	1.00							
U.S.	0.69	1.00						
Canada	0.65	0.44	1.00					
Germany	0.53	0.27	0.02	1.00				
France	0.86	0.52	0.51	0.33	1.00			
UK	0.76	0.39	0.57	0.28	0.66	1.00		
Italy	0.78	0.58	0.43	0.32	0.71	0.46	1.00	
Japan	0.68	0.26	0.25	0.46	0.48	0.45	0.36	1.00

Though some of these events are specific to a country or region, a casual comparison of the plots leads me to conclude that the indicators share similarities. This is confirmed by Table 2 which shows evidence of a positive comovement of the country indicators. Not surprisingly, they also tend to comove positively with the world indicator suggesting that country-specific events are of temporary importance.

Figure 2 shows the variable indicators which average across countries and lags. Some notable developments are readily apparent. The GDP and investment series, and to a lesser extent consumption, track the severe contractions in the mid 1970s and early 1980s, the U.S. recessions in 1991 and 2001, and the European one in 1992. The indicator series for the GDP deflator and interest rates decline over time, reflecting global disinflation. The series for government spending appears to be stable over time, except for the mid 1990s when government spending is weak for a couple of years and government budgets experienced rapid improvements, probably the result of fiscal consolidation in Europe following the Maastricht treaty in 1992. Moreover, monetary aggregates decline steadily until the mid 1990s but rise thereafter. Finally, stock prices appear to be noisy even after taking averages across countries and time. The years 1974 (first oil shock), 1987 (stock market crash) and 2001 (U.S. recession) are associated with negative returns.

I report the correlation between the variable indicators in Table 3. Overall, correlations are lower for variable than for country indicators. A few exceptions are worth mentioning. GDP, consumption and investment show a positive comovement. Furthermore, the GDP deflator and interest rates tend to be positively correlated as well, while the government budget and the GDP deflator display a negative correlation.

I conclude, while it is desirable to have all of the variable indicators in the model, there is probably no need to include the full set of country indicators once the world indicator has been

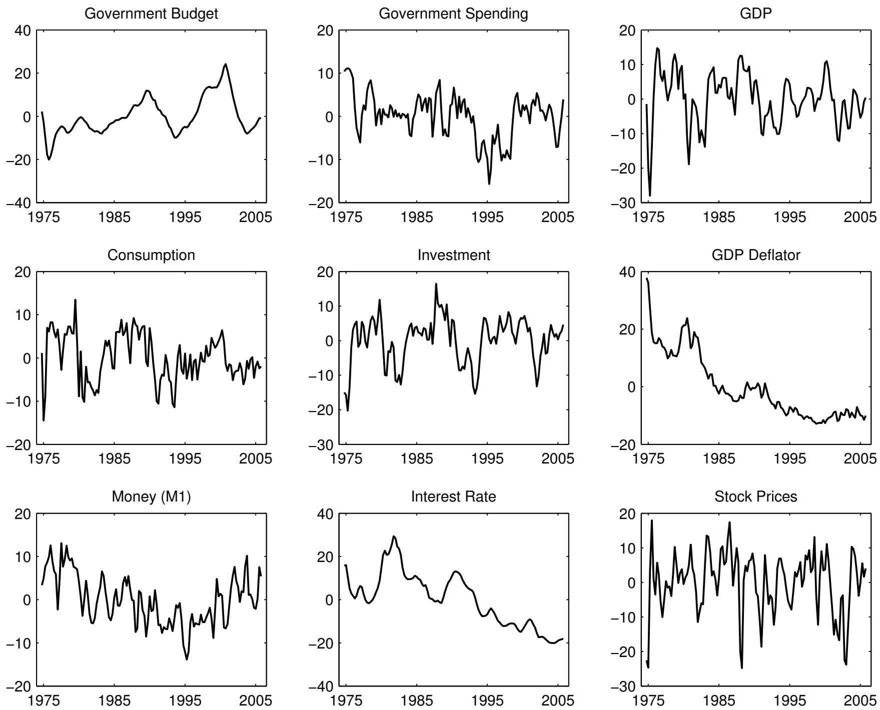

Figure 2: Variable indicators

added to the model. A bulk of the variation in the data can presumably be explained by common movements and adding country indicators leads to multicollinearity. Thus I do not consider a specification where all are included, but experiment with the following possibilties. First, I run regressions for each of the 63 series and include a world, nine variable, but no country indicator. Second, I perform the same regressions but add an U.S. country indicator for all countries, since the U.S. was the single largest member of the world economy during the sample period. Third, I replace the U.S. by a country indicator for the same country as the left hand side variable.

Table 4 reports the average fraction of the variance that is explained by the respective set of indicators, i.e. the average R^2. The upper panel shows the average across all countries and variables, the middle panel reports for each country the average across variables and the lower panel for each variable the average across countries. Several findings are of interest. First, about 40% of the variance across variables and countries is explained by the indicators. Second, the average R^2 is similar across countries, but not across variables. While movements in some variables are explained well (government budget, GDP deflator and interest rates), those in others are not (particularly, stock prices), reflecting different degrees of persistence. Third, adding country indicators to the model raises the R^2 by little. Consequently, I feel comfortable with the idea not to add all of the country indicators. However, I prefer to have the own country indica-

Table 3: Correlation between the variable indicators

	Gov. Budget	Gov. Spend.	GDP	Cons.	Invest.	GDP Defl.	Money (M1)	Int. Rate	Stock Prices
Gov. Budget	1.00								
Gov. Spending	−0.03	1.00							
GDP	0.15	−0.04	1.00						
Consumption	0.09	0.19	0.77	1.00					
Investment	0.30	−0.17	0.85	0.65	1.00				
GDP Deflator	−0.47	0.40	−0.09	−0.03	−0.29	1.00			
Money (M1)	−0.35	0.52	0.06	0.28	−0.01	0.41	1.00		
Interest Rate	−0.27	0.25	−0.14	−0.15	−0.31	0.74	−0.01	1.00	
Stock Prices	−0.06	−0.16	0.20	0.31	0.26	−0.07	0.16	0.00	1.00

tor included since it allows me to discriminate between developments specific to a country and those to the world.

5 Impulse responses

In this section, I present the impulse responses following shocks to U.S. monetary policy, the business cycle, stock prices and government spending. I estimate the multicountry VAR, fix coefficients at their OLS point estimates and draw one million Q matrices, leaving me with 289 responses that are consistent with the set of identifying restrictions. The acceptance ratio is low compared to related studies for two reasons. First, I identify four shocks simultaneously. And second, identification in a multicountry VAR is more difficult than in a standard VAR.

A common practice is to report the median of the posterior distribution, often in combination with percentile bands providing a measure of the range of responses. However, the distribution is across models and the median is not generated by a single model, i.e. by a single Q matrix. Thus draws from the posterior distribution are not orthogonal which is particularly problematic if multiple shocks are identified. In order to overcome this problem, I follow Fry and Pagan (2007) and choose a Q matrix that produces responses which are as close as possible to the median. This preserves the consensus view that the median is an informative statistic while orthogonality is retained. I normalize all responses by dividing by the standard deviation across all accepted draws and choose that Q which minimizes the sum of squared deviations from the median over all accepted draws, variables and time horizons:

Table 4: Average R^2 for regression of variables on indicator series

	Own Country Indicator	U.S. Country Indicator	No Country Indicator
All	0.40	0.40	0.39
U.S.	0.43	0.43	0.42
Canada	0.43	0.42	0.41
Germany	0.31	0.30	0.30
France	0.45	0.45	0.44
UK	0.38	0.39	0.37
Italy	0.46	0.46	0.45
Japan	0.36	0.35	0.34
Gov. Budget	0.81	0.79	0.77
Gov. Spending	0.21	0.21	0.20
GDP	0.27	0.28	0.26
Consumption	0.15	0.15	0.14
Investment	0.26	0.26	0.25
GDP Deflator	0.69	0.70	0.68
Money (M1)	0.25	0.25	0.24
Interest Rate	0.88	0.88	0.87
Stock Prices	0.10	0.11	0.10

Notes: Table shows the average fraction of the variance that is explained by the indicator series, i.e. the average R^2. The upper panel reports the averages across all countries and variables, the middle panel shows for each country the averages across variables and the lower panel for each variable the averages across countries. 'No Country Indicator' means that each variable is regressed on a world, all variable, but not on a country indicator. 'U.S. Country Indicator' indicates that the U.S. country indicator is included in all regressions. 'Own Country Indicator' means that the country indicator added to the right hand side of the regression refers to the same country as the left hand side variable.

$$Q_s^{\star} = argmin \sum_{i=1}^{4} \sum_{j=1}^{63} \sum_{k=0}^{24} \left(\frac{\phi_{ijk}\left(Q_s\right) - med\left(\phi_{ijk}\right)}{std\left(\phi_{ijk}\right)} \right)^2 \tag{7}$$

where $\phi_{ijk}\left(Q_s\right)$ is the response of variable $j = 1, ..., 63$ to shock $i = 1, ..., 4$ at horizon $k = 0, ..., 24$ generated by model $s = 1, ..., 289$.

The set of admissible models is thus reduced from 289 to 1 and I construct impulse responses and multicountry VAR shocks (this section) as well as a forecast error variance decomposition (next section) on the basis of the selected model. In order to summarize the information, I average statistics for Canada, Germany, France, UK, Italy and Japan and present results for this panel of countries and the United States.

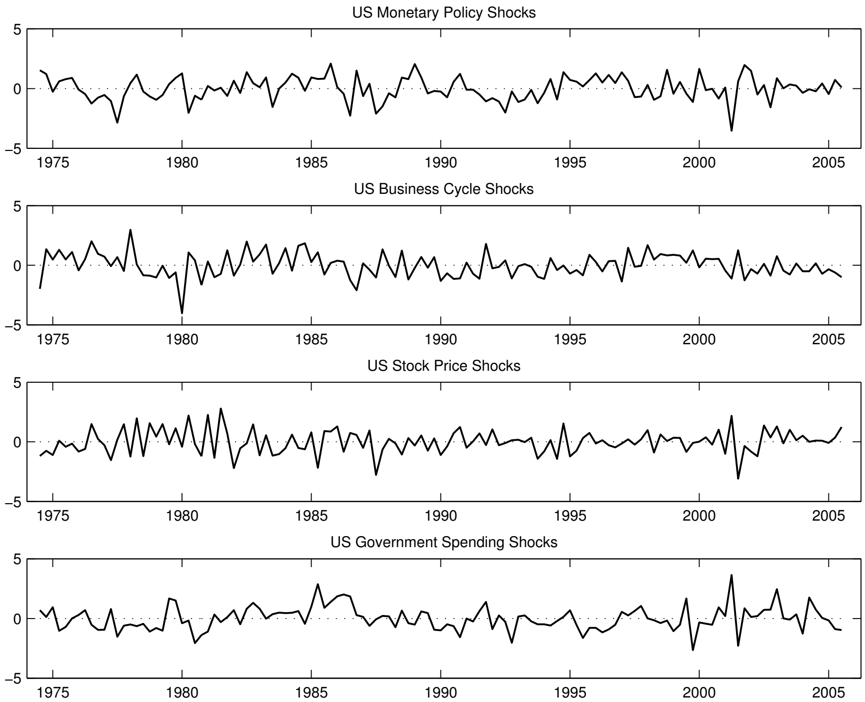

Figure 3: Estimated multicountry VAR shocks. Notes: Entries are percent.

5.1 U.S. monetary policy shocks

I show the estimated U.S. monetary policy shocks in the first panel of Figure 3. The stance of monetary policy in the United States is loose in the mid and late 1970s, but tight around 1980 following the appointment of Paul Volcker as chairman of the Federal Reserve. Moreover, the series displays negative innovations in 1987 and 2001, indicating an accomodative role of U.S. monetary policy in response to the U.S. stock market crash and the terrorist attacks on 9/11, respectively. Furthermore, the unexpected tightening around 1994-95 coincides with U.S. bond market turbulences. Overall, the estimated shocks mirror important U.S. monetary episodes, suggesting that the series is plausible.

Figures 4 and 5 show the impulse responses following a shock to U.S. monetary policy for the United States and the panel of other G-7 countries, respectively. I report the responses at each horizon between 0 and 24 quarters after the shock. Consider first the transmission within the United States. By construction, the shock has a positive effect on the interest rate but a negative impact on the monetary aggregate and the GDP deflator for a year throughout. As a consequence, real consumption and real investment contract on impact and are below their initial level for most of the following six years. Similarly, real GDP falls after the monetary policy

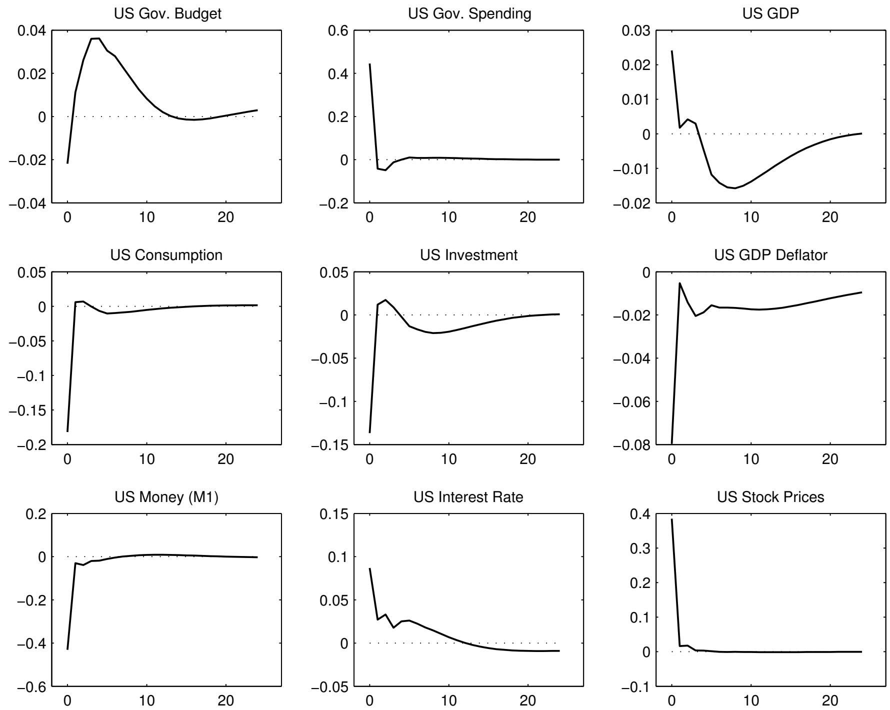

Figure 4: Impulse responses to U.S. monetary policy shock for the United States. Notes: Entries are deviations from baseline in percent; horizontal axis denotes quarters after the shock.

shock but displays a less intuitive postive response in the short-run. Surprisingly, the government budget improves in the years after the shock even though real activity is contracting. I presume that U.S. monetary and fiscal policy were somewhat coordinated over the sample period and that the monetary tightening is accompanied by an increase in taxes. Furthermore, stock prices rise in response to the monetary policy shock which is counterintuitive. However, I simultaneously identify an orthogonal shock that depresses stock prices for four quarters by construction and hence stock prices have the tendency to rise in response to other shocks. Overall, the responses settle around zero within a reasonable period of time, suggesting that the model is stable.

With respect to the transmission to the panel of other G-7 countries, I find that the U.S. monetary policy shock produces foreign responses that are similar to those for the United States. The main differences are in the effects on interest rates and government spending. While U.S. interest rates rise on impact and decline steadily thereafter, the positive effect on foreign interest rates builds up gradually over time, resulting in a hump-shaped response. Moreover, U.S government spending increases after the U.S. monetary policy shock but foreign government spending is below its initial level for about a year after the shock.

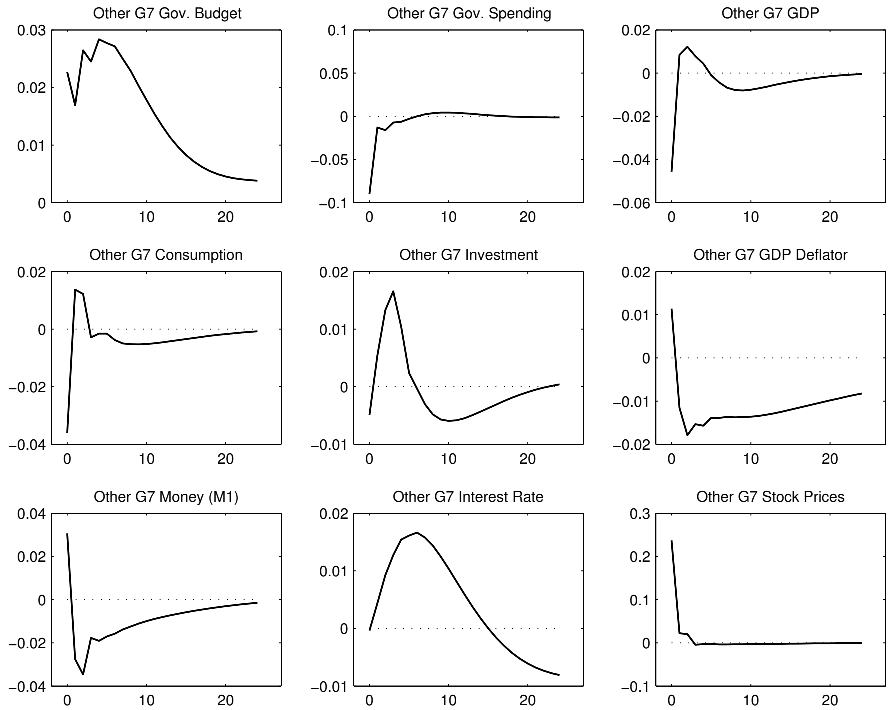

Figure 5: Impulse responses to U.S. monetary policy shock for the other G-7 countries.
Notes: See Figure 4.

5.2 U.S. business cycle shocks

The second panel of Figure 3 shows the estimated U.S. business cycle shocks. Negative innovations coincide with the 1973-75 and 1980 NBER recession dates, while that of 1981-82 is not picked up. Moreover, the contraction of 1990-91 is apparent but the mild recession of 2001 is not different from other shocks. Furthermore, the series shows a number of positive innovations in the early and mid 1980s and late 1990s, reflecting the recovery after the double dip recession and the 'new economy boom', respectively. In addition, the business cycle series is less volatile after 1985, consistent with the idea of a 'great moderation'. In sum, the estimated series is a plausible description of the cyclical behavior of the U.S. economy over the sample period.

I show the impulse responses to a contractionary U.S. business cycle shock for the United States in Figure 6. By construction, real GDP, real consumption and real investment fall after the shock and the government budget deteriorates. The effect on the budget, but not on real activity, is persistent even after removing the restriction. Fiscal balance is restored not until three years after the shock. However, real activity variables are expressed in quarterly growth rates and not in levels, hence it is not surprising that their responses return to their initial level soon after removing the restriction.

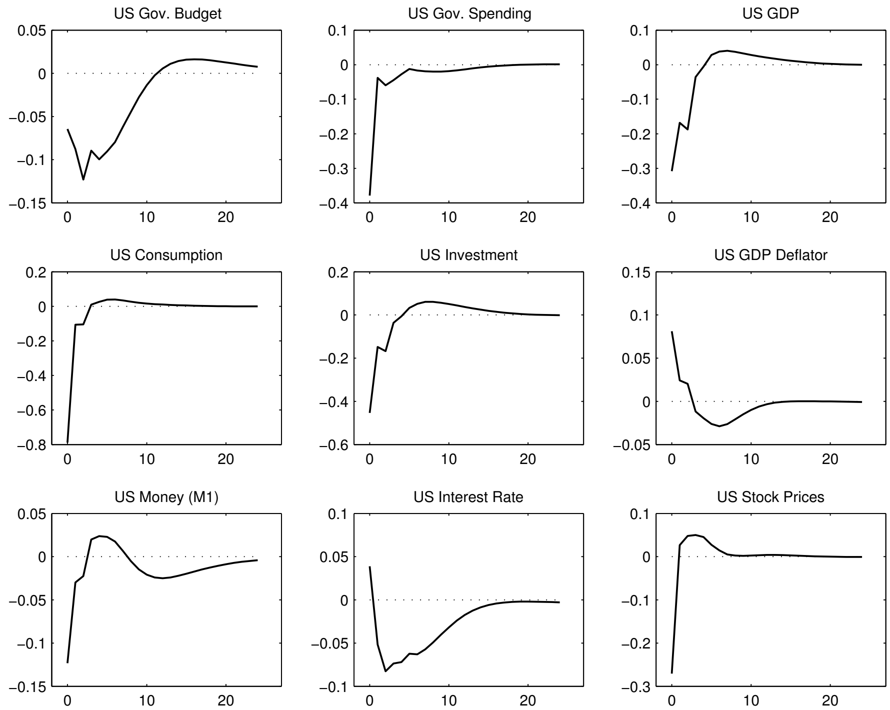

Figure 6: Impulse responses to U.S. business cycle shock for the United States. Notes: See Figure 4.

What are those shocks? So far, business cycle shocks induce a positive comovement of real activity and the government budget, while I impose no restriction on the response of the GDP deflator, consistent with both supply and demand side shocks. Thus, the response of the GDP deflator provides an answer. As you can see, real activity and the GDP deflator are negatively correlated for years after the shock, suggesting that the shock is a supply side shock. Possible candidates are technology or oil price shocks. However, I am not interested in the exact nature of such shocks since the main purpose of identifying business cycle shocks is to control for their effect on stock prices.

In fact, stock prices are adversely affected by the contractionary business cycle shock on impact. However, they recover soon after. Most of the adjustment takes place within a few quarters, consistent with the idea that stock prices incorporate news on the state of the business cycle in a short period of time. Furthermore, government spending and interest rates fall after the shock, suggesting an accomodative role for U.S. monetary policy, but not U.S. fiscal policy, in dealing with the contraction in real activity.

Finally, we can see from Figure 7 that the U.S. business cycle shock induces adjustments within the other G-7 countries that are similar to those for the United States. Though foreign

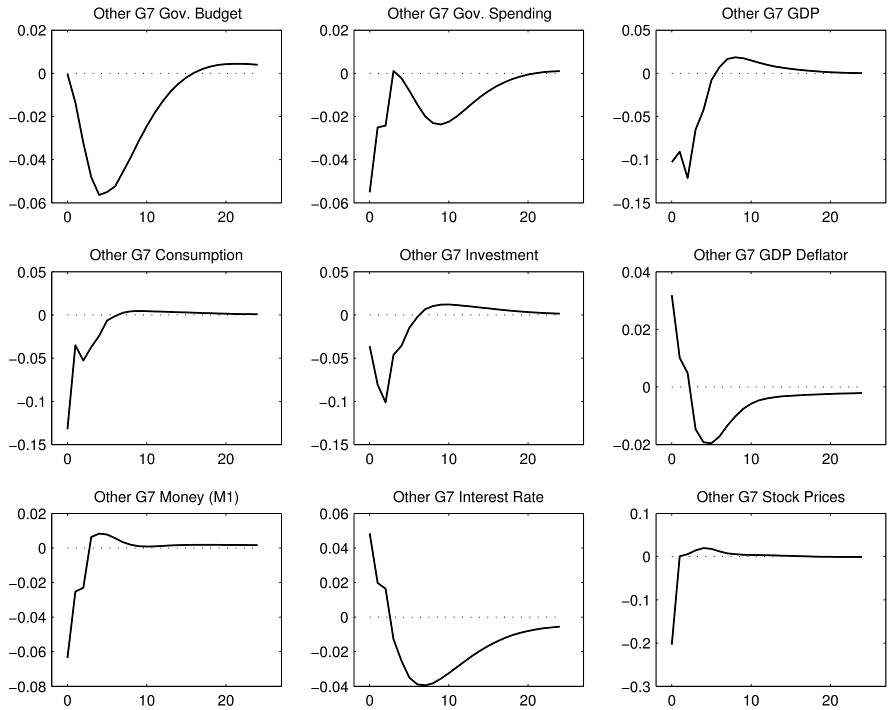

Figure 7: Impulse responses to U.S. business cycle shock for the other G-7 countries.
Notes: See Figure 4.

real activity variables display slightly delayed responses, the results support the view that real activity across G-7 countries is highly synchronized (see, e.g., Canova et al., 2007, among others).

5.3 U.S. stock price shocks

I show the estimated U.S. stock price shocks in the third panel of Figure 3. The series is volatile in the late 1970s and early 1980s and less volatile during the pronounced bull market 1982-2000. In particular, the 1995-2000 stock market boom is associated with a decline in volatility, consistent with the idea that stock returns and volatility are negatively correlated. Furthermore, the series displays negative innovations to U.S. stock prices in 1987 (the U.S. stock market crash) and 2001-03 (the U.S. bear market). In sum, the estimated shocks reflect important U.S. stock market events and appear to be plausible.

Figure 8 shows the impulse responses to an U.S. stock price shock for the United States. The stock price shock is orthogonal to the monetary policy shock, the business cycle shock and the government spending shock and stock prices decline for a year. However, I do not restrict the response of any other variable. As you can see from Figure 8, the response for stock prices immediately returns to zero once I remove the restriction, reflecting the low persistence

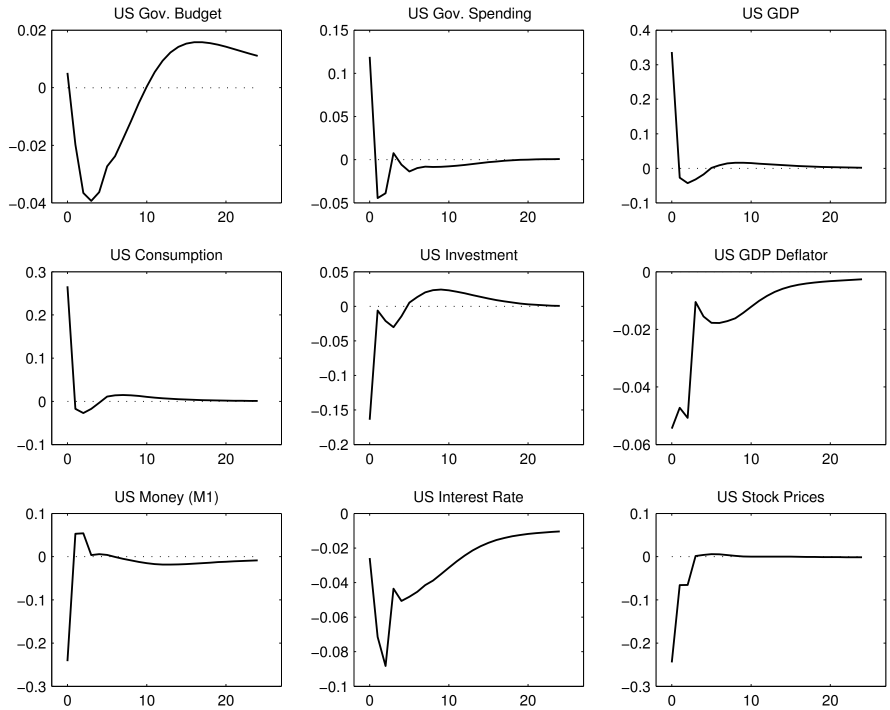

Figure 8: Impulse responses to U.S. stock price shock for the United States. Notes: See Figure 4.

of stock returns. Furthermore, the shock has a clear implication for the GDP deflator. The GDP deflator falls on impact and is below its initial level for the following six years. In contrast, I do not obtain a clear-cut result regarding the effect on real activity. While real investment falls on impact, real GDP and real consumption display positive responses. Thereafter, all three variables contract for a few quarters before returning to their initial level. A possible explanation for the improvement of real GDP in the short-run is that both U.S. monetary and fiscal policy are accomodative in response to the stock price shock. Government spending increases on impact, while the government budget and interest rates are both falling over time.

I conclude that the U.S. stock price shock does not qualify as a demand side business cycle shock as often argued in the literature (see, e.g., Fratzscher et al., 2007, among others). There is at best weak evidence of a positive comovement of stock prices, real GDP, real consumption, real investment and the GDP deflator. Given that the business cyle shock of the previous section turns out to be a supply side shock, a positive comovement would be possible even when requiring orthogonaliy between stock price and business cycle shocks.

Are the sign restrictions confusing shocks? Seems unlikely since I control for monetary policy, business cycle and government spending shocks when identifying shocks to stock prices.

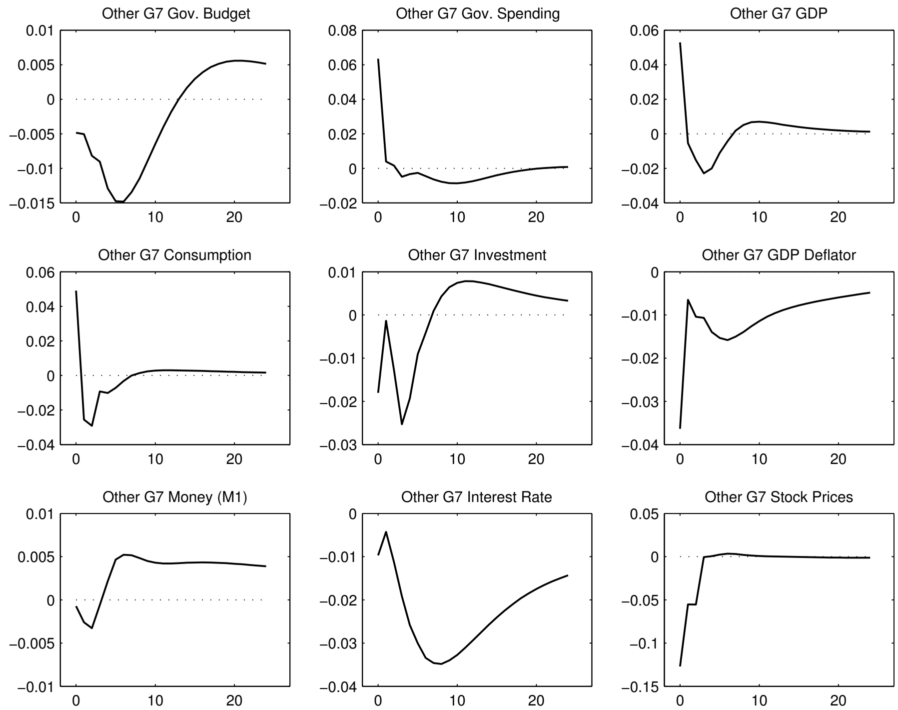

Figure 9: Impulse responses to U.S. stock price shock for the other G-7 countries. Notes: See Figure 4.

Of course, there are other candidates that may be relevant in this context, such as investment-efficieny shocks. As for the stock price shock in Figure 8, investment-efficiency shocks lead to a negative correlation between consumption and investment. However, investment-efficiency shocks are also associated with a positive correlation between real GDP and investment, which is not the case for the stock price shock. Thus, it seems unlikely that the stock price shock is an investment-efficiency shock.

As you can see from Figure 9, the U.S. stock price shock produces responses for the other G-7 countries that are similar to those for the United States. In particular, the shock is instantaneously incorporated in foreign stock prices, reflecting the close linkages between international stock markets. However, it seems that the negative effect of the decline in stock prices on real activity is larger over the medium-term for the other G-7 countries as compared to the United States.

5.4 U.S. government spending shocks

I show the estimated U.S. government spending shocks in the last panel of Figure 3. Overall, breaks in the series appear to be correlated with changes in the presidential terms. The esti-

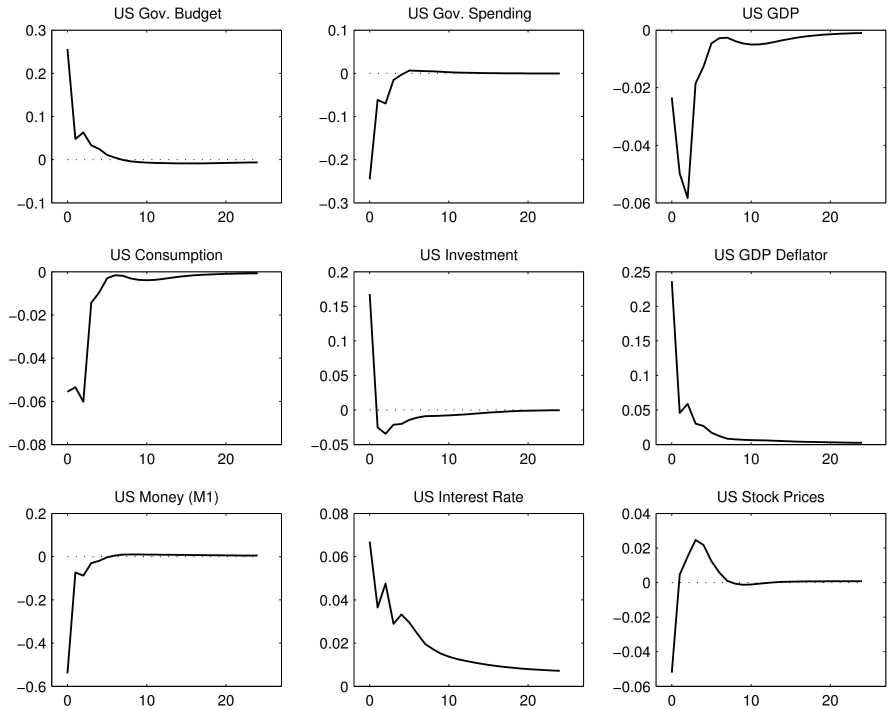

Figure 10: Impulse responses to U.S. government spending shock for the United States.
Notes: See Figure 4.

mated government spending shocks are negative on average in the late 1970s and early 1980s, indicating a restrictive fiscal policy during the presidencies of Gerald Ford and Jimmy Carter. In contrast, the Reagan era 1981-89 is associated with a series of positive shocks. In particular, U.S. fiscal policy is expansionary at the beginning of his second term in 1985, thanks to tax reductions and increased military defense spending. However, U.S. fiscal policy becomes restrictive after the election in 1989 and the presidencies of George Bush senior and Bill Clinton coincide with a number of negative shocks. Finally, the series is volatile during the first term of George Bush junior 2001-05, while the peaks in 2001 and 2003 indicate the military build ups associated with the wars in Afghanistan and Iraq, respectively. Of course, I cannot rule out that some of the estimated shocks reflect permanent changes in the conduct of U.S. fiscal policy rather than unsystematic fluctuations.

Figure 10 shows the impulse responses to an U.S. government spending shock for the United States. Such a shock reduces real government spending for one year while the government budget is restricted to improve. It also reduces real GDP and real consumption. Both variables fall on impact and are below their initial level for the following six years. In contrast, real investment rises on impact before falling over time, consistent with the textbook view of a crowding-in

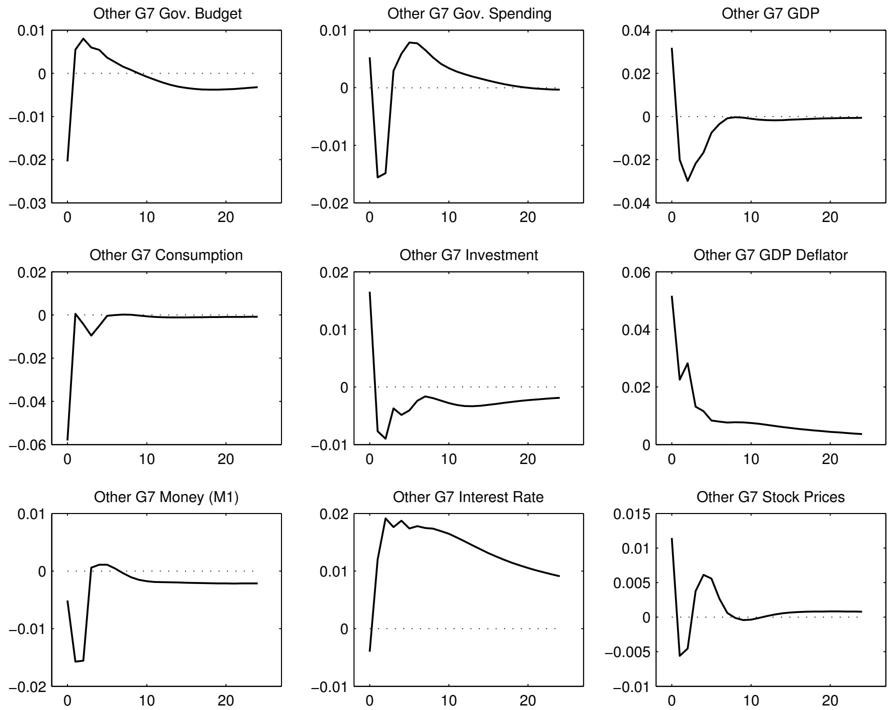

Figure 11: Impulse responses to U.S. government spending shock for the other G-7 countries. Notes: See Figure 4.

effect of the fiscal tightening. The positive effect on real investment seems to come from a reduction in real interest rates. Though both the interest rate and the GDP deflator rise after the shock, the GDP deflator increases stronger, suggesting a fall in real interest rates. The negative correlation between real government spending on the one hand and the GDP deflator as well as the interest rate on the other hand is less intuitive. However, such a finding is not uncommon in the fiscal policy literature (see, e.g., Mountford and Uhlig, 2005, among others). Finally, stock prices fall on impact, reflecting the contraction in real activity but recover thereafter.

I end this section by presenting the impulse responses for the other G-7 countries in Figure 11. It appears that the U.S. government spending shock is not directly transmitted to foreign fiscal policy variables. Both government spending and the budget display responses that are different to those of their U.S. counterparts. While the government budget has the tendency to fall rather than to improve over time, government spending is above its initial level after a year. However, the remaining variables follow their U.S. counterparts closely. Thus, the U.S. government spending shock contracts foreign real GDP and real consumption over the medium-term while real investment is crowded in on impact but falls thereafter. In addition, foreign interest rates and the GDP deflator increase.

6 Forecast error variance decomposition

In this section, I present a forecast error variance decomposition and assess how much of the variation in the variables can be accounted for by shocks to U.S. stock prices as compared to monetary policy, business cycle and government spending shocks. I report the numbers for the United States in Table 5 and those for the panel of other G-7 countries in Table 6. Both tables show the variance shares at forecast horizons of 24 quarters. I consider long-term forecast horizons for two reasons. First, the identification uncertainty is large at the short-end and not all of the variables display on-impact responses that are plausible. Calculating variance shares at long-term forecast horizons avoids that the results are dominated by potentially implausible short-term forecasts. Second, I am interested in the long-term predictive ability of stock price shocks for fluctuations in real activity variables and the GDP deflator rather than in their role at business cycle frequencies. Furthermore, I do not compute the total variance of the 24-step ahead forecast error but only that part which is explained by the four shocks. Given the dimensionality of the model, this seems reasonable. Consequently, the variance shares exactly sum to 100 percent even though the model is only partially identified.

With respect to the United States, I find that government spending and monetary policy shocks have no explanatory power for movements in real GDP, real consumption and real investment. Both shocks explain less than 10% of the variation in real activity at a 6-year horizon. Thus, monetary policy shocks have either little real effects in the long-run or their size is too small to be important in relation to other shocks. In contrast, monetary policy shocks have large effects on the monetary aggregate, stock prices and government spending, while government spending shocks account for a substantial fraction of the variation in the GDP deflator and the monetary aggregate. But given that government spending shocks explain 66% of the variation in the GDP deflator and monetary policy shocks account for 46% of the variation in government spending, it seems likely that the identification scheme cannot exactly disentangle both shocks. As already mentioned, a possible explanation is that U.S. monetary and fiscal policy were coordinated over the sample period. However, I am not too concerned about this drawback since I am not interested in monetary policy and government spending shocks per se but consider them to filter out their impact on stock prices.

Not surprisingly, U.S. business cycle shocks explain the largest fraction of the variation in real GDP, real consumption and real investment. Between 57% and 85% of the variation in real activity is due to such shocks. Moreover, about half of the movements in the government budget are explained by changes in the business cycle and the other half by exogenous innovations to fiscal policy. In addition, business cycle shocks account for 40% of the variation in the interest

Table 5: Forecast error variance decomposition for the United States

	Variability due to shock to			
	U.S. Mon. Policy	U.S. Business Cycle	U.S. Stock Prices	U.S. Gov. Spend.
Gov. Budget	4	43	6	47
Gov. Spending	46	35	4	16
GDP	1	57	40	2
Consumption	4	85	10	1
Investment	6	76	9	9
GDP Deflator	12	11	10	66
Money (M1)	32	4	12	52
Interest Rate	13	40	33	14
Stock Prices	49	27	23	1

Notes: I show the contribution in percent after 24 quarters.

rate, supporting the view that the largest fraction of the variation in interest rates is due to the endogenous part of monetary policy, i.e. the systematic response to shocks other than monetary policy shocks.

How much of the variation in U.S. variables cannot be attributed to shocks to U.S monetary policy, the business cycle and government spending and is thus due to U.S. stock price shocks? As you can see, only 23% of the variation in stock prices is due to own innovations, supporting my idea that controlling for other shocks is important when studying the transmission of stock price movements. Moreover, about one third of the variation in the interest rate but less than 10% of the variation in government spending and the budget is due to stock price shocks, suggesting an active role for the monetary authority, but not fiscal authority, in dealing with stock price movements. The effects of U.S. stock price shocks on real activity and the GDP deflator are less clear-cut. While stock price shocks explain 40% of the variation in real GDP, their impact on real consumption, real investment and the GDP deflator is small. Given that real consumption and real investment make up a large fraction of real GDP, the impact of stock price shocks on real GDP must hence come from elsewhere, presumably through the trade balance.

With respect to the transmission of U.S. shocks to other G-7 countries, I find that U.S. business cycle shocks account for the largest fraction of the variation across all foreign variables. Business cycle shocks explain between 28% of the variation in case of the GDP deflator and 63% for real GDP, reflecting an international business cycle. Since U.S. monetary policy shocks have little effects on U.S. real activity, it is not surprising that their impact on foreign real actvity

Table 6: Forecast error variance decomposition for the other G-7 countries

	Variability due to shock to			
	U.S. Mon. Policy	U.S. Business Cycle	U.S. Stock Prices	U.S. Gov. Spend.
Gov. Budget	15	51	15	19
Gov. Spending	23	44	25	8
GDP	7	63	12	17
Consumption	8	48	13	31
Investment	9	62	16	14
GDP Deflator	22	28	21	29
Money (M1)	27	32	22	19
Interest Rate	9	42	36	13
Stock Prices	43	34	21	2

Notes: I show the contribution in percent after 24 quarters.

is small, explaining less than 10% of the variation in foreign real GDP, real consumption and real investment. In contrast, about a quarter of the variation in the GDP deflator and monetary aggregates and nearly half of the variation in foreign stock prices is due to U.S. monetary policy shocks. The latter result suggests that U.S. monetary policy is an important factor for movements in international stock prices.

Furthermore, I do not obtain evidence of a fiscal policy coordination among G-7 countries. U.S. government spending shocks account for a mere 8% of the variation in foreign government spending at a 6-year forecast horizon. Moreover, their effect on foreign government budgets is moderate, explaining less than 20% of the variation. Of course, I cannot rule out some degree of policy coordination at short-term horizons or over the business cycle.

Overall, U.S. stock price shocks have a moderate impact on foreign variables, explaining between 13% and 36% of the variation. Consistent with the findings for the United States, only 21% of the variation in foreing stock prices is due to U.S. stock price shocks, U.S. monetary policy and business cycle shocks are more relevant. Moreover, I find that 36% of the variation in foreign interest rates is explained by U.S. stock price shocks. As for the United States, this number suggests a strong response of monetary policy to stock price movements. In addition, I obtain evidence of a notable effect of U.S. stock price shocks on foreign government spending and the budget, suggesting a more active role for fiscal policy in the other G-7 countries in dealing with stock price movements as compared to the United States. Finally, U.S. stock price shocks explain between 13% and 16% of the variation in foreign real activity, while 21% of the variation in the GDP deflator are due to such shocks. These numbers are larger than those for U.S. monetary policy shocks but smaller than for U.S. business cycle shocks.

7 Conclusion

This paper examines the transmission of U.S. stock price movements to real activity and prices in G-7 countries in the period 1974-2005. I achieve identification by imposing a small number of sign restrictions on impulse responses, while controlling for monetary policy, business cycle and government spending shocks. In contrast to related studies, the approach does neither rely on potentially implausible short-run restrictions nor is it dogmatic with respect to the nature of stock price shocks. The paper is an application of the novel multicountry VAR methodology of Canova and Ciccarelli (2009). I prefer the multicountry VAR to conventional panel data approaches since it has a number of appealing features. Among others, it allows for cross-country lagged interdependencies, heterogeneous dynamics and time series of moderate length.

The results are as follows. U.S. stock price movements are important for fluctuations in G-7 real activity and prices, even when controlling for others shocks. They explain between 9% and 40% of the variation in real activity for the United States and 12% to 16% for the other G-7 countries. Moreover, between 10% and 21% of the variation in the GDP deflator across G-7 countries is due to such shocks. However, these numbers are smaller than those for U.S. business cycle shocks. This finding, together with the observation that stock price shocks do not induce a positive comovement of real activity and prices, leads me to conclude that shocks to stock prices do not qualify as demand side business cycle shocks. Furthermore, the transmission of U.S. monetary policy, business cycle, stock price and government spending shocks is similar across the United States and the other G-7 countries.

Finally, I want to acknowledge a limitation and point to a direction for future research. In this paper, I leave the responses of many variables agnostically open and use the rule of Fry and Pagan (2007) to narrow down the set of admissible models. Alternatively, I could combine the sign restrictions with bounds restrictions on the magnitude of certain elasticities, such as the government spending multiplier. Kilian and Murphy (2009) propose such a procedure in the context of oil market VARs to reduce the number of models. I would expect that imposing additional restrictions reduces the overall identification uncertainty and the number of counter-intuitive on-impact responses.

A Transformation of the covariance matrix

Premultiply $Y_t = X_t\delta + u_t$ with

$$P = \begin{pmatrix} P_1^{-1} & 0 & \dots & 0 \\ 0 & I_G & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & I_G \end{pmatrix}_{NG\times NG}$$

which yields

$$PY_t = PX_t\delta + \epsilon_t,$$

where $\epsilon_t = (\epsilon_{1t}', u_{2t}', ..., u_{Nt}')$ and thus

$$\Sigma_\epsilon = E\left(\epsilon_t\epsilon_t'\right) = \begin{pmatrix} I_G & \Sigma_{\epsilon_1,u_2} & \dots & \Sigma_{\epsilon_1,u_N} \\ \Sigma_{u_2,\epsilon_1} & \Sigma_{u_2} & \dots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ \Sigma_{u_N,\epsilon_1} & \Sigma_{u_N,u_2} & \dots & \Sigma_{u_N} \end{pmatrix}_{NG\times NG}$$

is the transformed covariance matrix with $\Sigma_\epsilon = P\Sigma_u P'$.

B The data

Data on national accounts and government budget outcomes are from the OECD Economic Outlook database. I use the series CGV, IGV, GDPV, CPV, IPV, PGDP, and NLGXQ. Since the June 2006 volume is the most recent one that provides estimates of quarterly government budget outcomes for the G-7 countries (not for Italy though), I do not consider data later than 2005Q4. I obtain the series for Italy from the December 2004 vintage even though the last four observations are forecasts. Data on interest rates (3-month Treasury Bill or money market rates), monetary aggregates (M0 for the UK, M1 otherwise) and stock prices are from IMF's International Financial Statistics database. For Italy and France, M1 data are from Eurostat. In case of Germany, France and Italy, I use national figures on interest rates and monetary aggregates up to 1998Q4 but those for the euro area thereafter. Except for stock prices and interest rates, I deseasonalize all series.

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