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The "price puzzle" in the monetary transmission VARs with long-run restrictions

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ABSTRACT

This study addresses the "price puzzle" — a positive response of prices to monetary tightening in VAR models. By using long-run instead of the usual short-run restrictions on the US data including output, prices and interest rate, we find that monetary tightening had a negative effect on prices.

1. Introduction

In structural vector autoregressive (VAR) models the response of prices to a monetary shock is sometimes contrary to economic theory remarkably positive — a phenomenon so persistent in the US data that it is known as the "price puzzle". The puzzle appears if a measure of real activity, prices and a short-term interest rate are included and a Cholesky identification scheme is applied with interest rate ordered last (surveyed in Christiano et al., 1999). In the VAR literature additional variables are usually included to resolve this puzzle. Sims (1992) proposed introduction of the commodity prices and Giordani (2004) suggested adding the potential output.

We instead argue that this counterintuitive result disappears if Cholesky identification is replaced by long-run restrictions. The advantage of long-run identification is that there is no need for additional variables besides prices, interest rate and output. To the best of our knowledge the paper which points out this result is Jang and Ogaki (2001), however they study the monetary transmission to the exchange rates and not prices. Long-run restrictions have not been used in the monetary VAR literature, which we believe is mainly due to the critique of Faust and Leeper (1997) who claim that parameters capturing the long-run effects are likely biased in small samples, leading to possibly wrong inference.

This paper addresses the puzzle by estimating a structural cointegrated VAR model. We estimate the system subject to long-run restrictions, as proposed by Breitung et al. (2005). We find that output, inflation and interest rates are integrated of order one (also found by e.g. Juselius, 1998) and that at most one cointegrating relation exists among them. To identify the system we use this information and the assumption that only the monetary shock has a short-run effect on output and prices. Then, we estimate two structural cointegrated VAR models on the US data, one from 1955 up to 1977 and the other from 1981 up to 2004. In this way we avoid the structural instability around the 1980 (as found e.g. by Clarida et al., 1998 or Galí et al., 2003). We show that a restrictive monetary policy shock has a negative gradual effect on the price level and a negative, but a quicker effect on the output in the period before as well as after the 1980.

In the reminder of the paper, in Section 2 we test for unit roots, cointegration and estimate the reduced form models. In Section 3 we present the identification assumptions and the impulse responses. Section 4 concludes.

2. Unit roots, cointegration and reduced form models

In our analysis we include three variables, the US short-term interest rate i_t (the three-month Federal Funds Rate), the inflation rate π_t and the log of real output y_t, all of them on a quarterly bases. The source of the data is Datastream.

First, variables in first differences and then in levels were tested for unit roots. The augmented Dickey Fuller (ADF) tests for both periods

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Table 1
Unit root tests.

		Δy_t	y_t	Δi_t	i_t	$\Delta \pi_t$	π_t
Pre-1979 period	ADF test stat.	−8.38***	−2.11	−10.32***	−1.45	−9.39***	−1.21
	AR lags included+	3 (3)	2 (2)	3 (3)	2 (2)	4 (4)	3 (3)
	Deterministics	Trend	Const.	Const.	Const.	Const.	Const.
Post-1981 period	ADF test stat.	−9.32***	−2.03	−9.38***	−1.21	−6.78***	−0.96
	AR lags included+	2 (2)	1 (1)	5 (5)	4 (4)	4 (4)	4 (4)

Notes: + — In brackets the value indicates the AIC suggestion. *** — H_0 rejected at 1% level.

Table 2
Johansen trace statistics.

Deterministics included	H_0	Number of lagged differences+		Crit. values	
		Pre-1979 3 (3)	Post-1981 2 (2)	90%	95%
Constant and trend	$r=0$	81.56***	69.25***	39.73	42.77
	$r=1$	20.48	18.16	23.32	25.73
	$r=2$	8.01	4.03	10.68	12.45
Orthogonal trend	$r=0$	27.32**	28.95**	27.16	29.80
	$r=1$	9.69	6.63	13.42	15.41

Notes: + — In brackets the value indicates the AIC suggestion. Critical values from Johansen (1995), Tables 15.4 and 15.5. *** — H_0 rejected at 1% level, ** — H_0 rejected at 5% level.

are shown in Table 1 below. For output series, we include a trend in the ADF regression, while for the interest rate and inflation only a constant is present. For the variables in first differences, the deterministics was adjusted properly. We include as many lags as suggested by the Akaike information criterion (AIC). In both periods, at the 95% confidence level, the ADF test cannot reject the unit root hypothesis for the variables in levels, while it does reject the unit root for variables in first differences. We concluded that all three variables have a unit root.

Then we test for the number of cointegrating relations among the three variables with the Johansen trace test. In Table 2 below the test results are shown. The test is performed including the trend in the cointegrating relation or orthogonal to it, while the number of AR lags is chosen according to the AIC. Zero cointegrating rank in the system is rejected at the confidence level of 95%, while rank one is not, which shows that there is at most one cointegrating relation in the model.

The reduced form VEC model

$$\Delta y_t = \alpha[\beta' y_{t-1} + \mu_1 t] + \sum_{i=1}^{p} C_i \Delta y_{t-i} + C + u_t \quad (1)$$

is estimated, where $y_t = [i_t, \pi_t, ip_t]'$ and Δ denotes the differencing operator. The $\alpha\beta'$ matrix is the reduced rank matrix with the rank equal to the number of cointegrating relationships r, in our case 1. α denotes the matrix of loading coefficients and β is the matrix of the r cointegrating relationships. Γ_i is the (3×3) matrix of short-term AR parameters of i-th lag and u_t is the vector of reduced form residuals. The models are estimated with the reduced rank regression.

We argue that the reduced form cointegrated VAR models with three lags in first differences, trend and a constant included in the cointegrating relation, and seasonal dummies included in the model, produce good results in terms of absence of residual autocorrelation and ARCH effects in the residuals. The residual correlation is tested with portmanteau test up to lags 8 or 12 and Lagrange Multiplier (LM) tests for autocorrelation for lags one and two, while the ARCH was tested with the multivariate LM tests for ARCH. The results in Table 3 show that residuals of both periods exhibit no autocorrelation when and in addition no ARCH seems to be present. We conclude that the models obtained are a good description of the data.

3. Identification and impulse responses

The rank of the total impact part in the Granger representation of the cointegrated VAR model above is equal to the number of stochastic trends in the model. As in the theoretical Neo-Keynesian models on monetary policy, the monetary shock is restricted to have only transitory effects on the output, inflation and the interest rate (Clarida et al., 1998; Vlaar, 2004). In addition, from the cointegration analysis in the previous section, one cointegrating relation was found. Therefore at most one shock can have a transitory effect in the system. This follows since there cannot be more transitory shocks than there are cointegrating relations (for exposition check Lütkepohl, 2005). Therefore one column in the total impact part referring to the monetary policy shocks will consist of zeroes — in our case the first column. The other two columns (denoted by stars) are left unrestricted. So, the total impact part is

	Monetary policy shock	Inflation shock	Supply shock
i_t	0	*	*
π_t	0	*	*
ip_t	0	*	*

The calculation of restrictions is available in Lütkepohl (2005). By restricting one column to zero, we obtain two independent restrictions (the number of unrestricted columns times the number of cointegrating relations, which is in our case, two).

Since we need three independent restrictions ($(K-1)K/2$ in general, where K denotes the number of variables in the system (Lütkepohl, 2005)) one additional restriction has to be made in the contemporaneous impact part (in the notation of Lütkepohl this is the B matrix linking the structural shocks with reduced form residuals). In SVAR literature in most cases the decision lags argument was used. According to this, the inflation movements cannot affect the output

Table 3
Residual serial correlation and ARCH tests.

Period		Q_8^*	Q_{12}^*	LM_1	LM_2	$MARCH_{LM}$ (2)	$MARCH_{LM}$ (4)
Post-1981	Test stat.	72.50	114.78	16.59	28.05	93.35	173.23
	Asymp. distr.	χ^2 (55)	χ^2 (91)	χ^2 (9)	χ^2 (18)	χ^2 (72)	χ^2 (144)
	p-value	0.06	0.05	0.06	0.06	0.05	0.05
Pre-1978	Test stat.	64.35	113.89	12.68	18.69	72.34	168.07
	Asymp. distr.	χ^2 (54)	χ^2 (90)	χ^2 (9)	χ^2 (18)	χ^2 (72)	χ^2 (144)
	p-value	0.15	0.05	0.17	0.41	0.46	0.08

Notes: Q_p^* — multivariate Ljung Box portmanteau test tested up to the p-th lag.
LM_p — LM (Breusch–Godfrey) test for autocorrelation up to the p-th lag.
LJB_p^L — multivariate Lomnicki–Jarque–Bera test for non-normality from Lütkepohl (2005) with p variables included in the system.
$MARCH_{LM}$ (p) — multivariate LM test for ARCH up to the p-th lag.