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Identifying Sources of Business Cycle Fluctuations in Germany 1975–1998

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Abstract

In this paper, we estimate a small New Keynesian dynamic stochastic general equilibrium (DSGE) model for Germany for the period from 1975 to 1998 and use it to identify the structural shocks, which have driven the business cycle. For this purpose we apply indirect inference methods, that is we specify the parameters of the theoretical model such that simulated data mimics observed data as closely as possible. In addition to the identification of structural shocks, we uncover the unobservable output gap, which is a prominent indicator in business cycle analysis. Furthermore, we show to which extent each identified shock has contributed to the business cycle fluctuations.

JEL Classification: C32, C51, E32

Keywords: Business cycle accounting, dynamic stochastic general equilibrium models, Germany, indirect inference, New Keynesian macroeconomics

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1 Introduction

In this paper, we estimate a small dynamic stochastic general equilibrium (DSGE) model for Germany for the period from 1975 to 1998. We use the estimated model to identify the structural shocks, which have driven the business cycle, and to estimate the output-gap, which is an economically meaningful but unobservable variable. We compare our model-based output-gap to HP-filtered real GDP. The model-based decomposition seems superior to us because it relies on economic assumptions and not on a solely statistical decomposition. The period from 1975 to 1998 is interesting because several structural shocks occurred, for example the second wave of oil price shocks in the late 1970s and the shocks around the German reunification in 1990. Especially the nature of the economic shocks that origin in the German reunification are still not fully understood and have been subject to recent research, see Burda (2006) and Uhlig (2006), for example. We contribute to this literature by showing that the German unification was primarily accompanied by a pronounced demand shock but also followed by substantial negative productivity shocks.

The paper is organized as follows. In section 2, we present a small New Keynesian macroeconomic model, in section 3, we describe our estimation approach, and the structural economic analysis follows in section 4. Finally, section 5 offers a brief summary and conclusions. A technical appendix with detailed information on various steps of the analysis is available from the corresponding author upon request.

2 A Small Stylized Macroeconomic Model

We use a standard small New Keynesian macroeconomic model. Since these models have been discussed intensively in the recent literature, see for example Galí (2002), King (2000), McCallum and Nelson (1999a), Walsh (2003), and Woodford (2003), we only present our model specification without explaining it in greater detail. The endogenous variables of the model are consumption growth (Δc), output growth (Δy), consumption share in output (cy), short-term nominal interest rate (R), inflation rate (π) and output gap ($yg=y-y^*$). The main dynamics of the model are generated by three structural equations, namely an IS equation, a Phillips curve equation and a monetary policy rule, and four exogenous shocks.

Productivity growth and flexible price output. Like for example in McCallum and Nelson (1999b), we assume that the log flexible price (potential) output y^* is determined by an exogenous stochastic productivity process. More specifically, the change in the flexible price output follows an AR(1) process:

$$y_t^* = y_{t-1}^* + x_{at}, \quad x_{at} = \rho_a x_{a,t-1} + \varepsilon_{at}, \quad -1 < \rho_a < 1, \quad \varepsilon_{at} \sim N(0, \sigma_a^2).$$

IS equation (IS). The IS equation in New Keynesian macroeconomic models is derived from the optimizing behaviour of the representative household who seeks to maximize its utility while facing a budget constraint. Following the literature on estimated New Keynesian macroeconomic models, we allow for habit persistence in consumption. The resulting first order condition of the optimization problem is nonlinear and is therefore log-linearized. Since our model economy exhibits a stochastic trend in productivity, consumption does also follow a stochastic trend. Accordingly, we log-linearize a transformed version of the consumption Euler equation which does not contain the level of consumption but – like for example in Ireland (2001) – consumption divided by output, that is the consumption share *cy*. We show in the technical appendix that this procedure yields the following IS equation:

$$E_t\left[cy_t + a_1 cy_{t-1} + a_2 cy_{t+1} + a_3 cy_{t+2} + a_4 \Delta y_t + a_5 \Delta y_{t+1} + a_6 \Delta y_{t+2} + a_7\left(R_t - \pi_{t+1}\right)\right] = 0,$$

where the coefficients a_1 to a_7 follow directly from the inverse elasticity of intertemporal substitution σ and an habit persistence parameter h.

Resource constraint (RC). The resource constraint of the economy is given by

$$Y_t = C_t + X_{gt},$$

where Y_t denotes output, C_t consumption, and X_{gt} comprises all other GDP components. We divide the resource constraint by flexible price output Y_t^*:

$$YG_t = \frac{C_t}{Y_t^*} \cdot \frac{Y_t}{Y_t} + \frac{X_{gt}}{Y_t^*} = CY_t \cdot YG_t + \frac{X_{gt}}{Y_t^*},$$

such that after log-linearization around the steady state we have

$$yg_t \approx \frac{cy}{1 - cy} cy_t + x_{gt},$$

where x_{gt} is a stationary exogenous GDP shock:

$$x_{gt} = \rho_g x_{g,t-1} + \varepsilon_{gt}, \quad -1 < \rho_g < 1, \quad \varepsilon_{gt} \sim N(0, \sigma_g^2).$$

Phillips curve (PC). Inflation dynamics are described by the New Keynesian Phillips curve, which is derived from the forward-looking behaviour of firms who know that prices will be sticky for some time and therefore consider expected future changes in marginal costs in the price setting decision. Under the assumptions that real marginal costs depend on the output gap and that a fraction γ_b of the firms is backward-looking, we obtain the hybrid Phillips curve:

$$\pi_t = \gamma_b \pi_{t-1} + (1-\gamma_b)\beta E_t[\pi_{t+1}] + \kappa yg_t + x_{\pi t},$$

where $x_{\pi,t}$ represents a cost-push shock:

$$x_{\pi t} = \rho_\pi x_{\pi,t-1} + \varepsilon_{\pi t}, \quad -1 < \rho_\pi < 1, \quad \varepsilon_{\pi t} \sim N(0, \sigma_\pi^2)$$

and κ is related to the degree of price stickiness (the lower κ, the higher price stickiness).[1]

Monetary policy rule (MP). The model is closed by an interest rate rule, which reflects monetary policy:

$$R_t = \tau_R R_{t-1} + (1-\tau_R)(\tau_\pi \pi_t + \tau_y yg_t) + x_{Rt}, \quad 0 \le \tau_R < 1, \quad \tau_\pi > 1, \quad \tau_y > 0,$$

where x_{Rt} is a monetary policy shock:

$$x_{Rt} = \rho_R x_{R,t-1} + \varepsilon_{Rt}, \quad -1 < \rho_R < 1, \quad \varepsilon_{Rt} \sim N(0, \sigma_R^2).$$

The nominal interest rate R_t is the monetary policy instrument. It depends on the lagged interest rate (interest rate smoothing), inflation rate and output gap. It is well established in the literature that the interest rate policy by Deutsche Bundesbank until 1998 can be roughly described by such a simple interest rate rule, see Clarida and Gertler (1996).

Additional equations. The model is augmented with two additional equations, which represent definitions of observable variables. The growth rate of output is given by:

$$\Delta y_t = \Delta yg_t + \Delta y_t^*,$$

and consumption growth is equal to

$$\Delta c_t = \Delta cy_t + \Delta y_t.$$

Model solution. Following Uhlig (1999), the complete model can be summarized in the following system of equations:

[1] An empirical analysis of the Phillips curve for Germany can be found in Tillmann (2005).

$$
\begin{aligned}
0 &= Ay_{1t} + By_{1,t-1} + Cy_{2t} + Dz_t \\
0 &= E_t\left[Fy_{1,t+1} + Gy_{1t} + Hy_{1,t-1} + Jy_{2,t+1} + Ky_{2t} + Lz_{t+1} + Mz_t\right] \\
z_t &= Nz_{t-1} + \varepsilon_t .
\end{aligned}
$$

The four variables cy_t, R_t, π_t and yg_t are specified as endogenous state variables $y_{1,t}$, and Δc_t and Δy_t are stacked in the vector $y_{2,t}$ of other endogenous variables. The vector z_t contains the four exogenous shocks x_{at}, x_{gt}, $x_{\pi t}$ and x_{Rt}. The matrices A, B, …, N are coefficient matrices with appropriate dimensions. ε_t is a multivariate normally distributed and serially uncorrelated shock vector with variance-covariance matrix Σ_ε. The model is solved numerically for the recursive law of motion of the endogenous variables using the Uhlig (1999) toolkit. The recursive law of motion can in turn be used to calculate impulse responses and to simulate the model. However, for this purpose the structural parameters have to be specified numerically.

3 Estimating the Stylized Macroeconomic Model

3.1 Indirect Inference Estimation of DSGE Models

The indirect inference approach (Gourieroux et al., 1993, Smith Jr., 1993) that we use is the Extended Method of Simulated Moments (EMSM) and proceeds as follows. In the first step, an auxiliary statistical model that summarizes the statistical properties of the relevant observable variables is estimated. In a second step, the same variables are generated artificially using the theoretical DSGE model and a vector of start values for the structural parameters that have to be estimated. For the simulated data we estimate the same statistical auxiliary model and compute a weighted distance between the two sets of auxiliary parameters (observed and simulated data). In the third step, this weighted distance is minimized numerically with respect to the vector of structural parameters. This procedure delivers consistent and asymptotically normally distributed estimates of the structural parameters. These estimates are not necessarily efficient, especially if it is feasible to estimate the model with maximum likelihood (ML) methods. However, it is well known that efficiency of ML estimation depends on the correct specification of the likelihood function. In case of non-normal exogenous shocks or misspecification, indirect inference may be more robust.

In the choice of the auxiliary model, we follow Smith Jr. (1993) and apply reduced form vector autoregressions (VAR). Reduced form VAR models without any restrictions are able to capture the dynamic behaviour of a given set of variables very well. An alternative to matching reduced form VAR coefficients is to match the impulse responses estimated from a structural VAR and the impulse responses implied by the theoretical model, like for example in Christiano et al. (2005). However, since Christiano et al. (2005) do not estimate the model-based impulse responses from simulated data but compute them directly from the recursive law of motion, the econometric theory that has been developed within the indirect inference literature cannot be directly applied. Furthermore, impulse response matching relies on the correct identification of economic shocks in small or medium scale SVARs, which is a difficult and often ambiguous task, see for example Canova and Pires Pina (2005) and Chari et al. (2005).

3.2 Preliminary Data Analysis

We use the following variables in our empirical analysis: short-term nominal interest rate (R), GDP deflator inflation rate (π), log real private consumption per capita in prices of 1995 (c), and log real GDP per capita in prices of 1995 (y). The data is for West Germany for 1975 to 1990 and for reunified Germany from 1991 to 1998. In total we have 96 quarterly observations. The data sources and precise definitions of the variables are given in the technical appendix.

Integration and cointegration properties. Log consumption per capita and log GDP per capita follow a long-run trend and are subject to a structural break due to the German reunification. Appropriate unit root tests show that both variables are integrated of order one, see table 1. The table shows Augmented Dickey-Fuller *t*-Statistics together with the corresponding critical values.

Table 1: ADF unit root tests

	Constant		Constant and mean shift dummy		Constant, time trend and mean shift dummy		Broken time trend	
	t-Stat.	*p*	*t*-Stat.	*p*	*t*-Stat.	*p*	*t*-Stat.	*p*
5% critical value	-2.892		-3.340		-3.760		-4.240	
GDP	-2.463	1	-2.100	0	-3.457	0	-3.997	0
Consumption	-2.006	4	-0.025	6	-2.316	4	-2.871	6
Inflation	-8.190	0	-9.254	0				
Interest rate	-2.189	1	-2.286	1				
Consumption growth	-13.128	0	-13.920	0				
GDP growth	-12.097	0	-3.807	6				
Consumption share	-2.487	0	-4.840	0				

Notes: The table shows Augmented Dickey-Fuller *t*-Statistics. The null hypothesis that a variable is integrated of order one is rejected, if the corresponding *t*-Statistic is smaller than the critical value. *p* is the lag order of the ADF auxiliary regression, which has been chosen according to BIC. The 5% critical values are taken from MacKinnon (1996) for alternative A, Perron (1990) for alternative B, and Perron (1989) for alternatives C and D. All alternatives include two sets of seasonal dummies, namely centered seasonal dummies for the whole sample and centered seasonal dummies multiplied by the mean shift dummy DS9101.

While our tests clearly suggests that log consumption (c) and log output (y) exhibit a unit root, the null hypothesis of a unit root is rejected for their respective growth rates and for the consumption share $cy_t=c_t-y_t$. In case of the consumption share it has to be considered, that a mean shift occurred in the first quarter 1991 due to the German reunification. Accordingly, log consumption and log output are cointegrated and share the same stochastic trend.[2] The inflation rate (π) is also found to be stationary. For the nominal interest rate (R) the null hypothesis of a unit root is not rejected. However, since unit root tests have low power for highly persistent stationary variables, we assume in the following – like many other studies as well – that the nominal interest rate is stationary in order to meet the requirements of our theoretical framework.

Adjustment for seasonality and German reunification. With exception of the interest rate, all considered variables exhibit a strong seasonal pattern. We adjust consumption and output growth rates, inflation rate and consumption share for deterministic seasonality and for the structural break due to German reunification in order to facilitate the subsequent computations. More precisely, we estimate for these variables autoregressive models with nonlinear least squares and augment these models with two sets of seasonal dummies (until 1990, from 1991 onwards) and with mean shift and impulse dummies for the first quarter of 1991. The AR order is chosen by adding additional AR terms until the residuals do not exhibit

[2] For testing the non-stationarity of the consumption share we apply unit root test critical values because we do not estimate a cointegration vector but consider directly the consumption share.

any serial correlation anymore. Subsequently, the adjusted variables are constructed by subtracting the deterministic terms from the original variables, see the technical appendix for details.

4 Structural Analysis

4.1 Estimation of the Model

The result of the numerical minimization of the weighted distance between the two sets of auxiliary parameters depends on the choice of the starting values. We have chosen a *sophisticated* random search strategy in order to deal with this problem. We have set the starting values to economically plausible values – partially relying on preliminary OLS regressions for the model equations. We perturbed these starting values several times and started the minimization again. Finally, we have chosen that specification that leads to the lowest weighted distance. Table 2 shows the corresponding starting values and the estimated structural parameters. During the estimation process, we have excluded the habit persistence parameter h from estimation because it turned out that other values than zero actually increase the weighted distance.

Table 2: Estimated structural parameters

Parameter	Start values	Lower bound	Upper bound	Estimate	t-Statistic
		IS equation			
σ	5.0000	1.0000	∞	20.1551	1.7490
h	0.0000	0.0000	1.0000	0.0000	
		Phillips curve			
γ_b	0.3000	0.0000	0.9900	0.2045	0.2090
κ	0.1000	0.0100	∞	0.0100	0.1818
		Monetary policy rule			
τ_R	0.9300	0.0000	0.9900	0.8515	13.1709
τ_y	1.0000	0.0000	∞	0.7482	0.4721
τ_π	1.5000	1.0100	∞	1.0137	1.6985
		Productivity process			
σ_a	0.0070	0.0001	∞	0.0054	5.9795
ρ_a	0.0000	-0.9900	0.9900	0.0096	0.0383
		GDP shock			
σ_g	0.0180	0.0001	∞	0.0012	1.2466
ρ_g	0.5400	-0.9900	0.9900	0.7522	3.0408
		Cost push shock			
σ_π	0.0045	0.0001	∞	0.0024	2.0634
ρ_π	0.0000	-0.9900	0.9900	0.0003	0.0002
		Monetary policy shock			
σ_R	0.0017	0.0001	∞	0.0023	13.7618

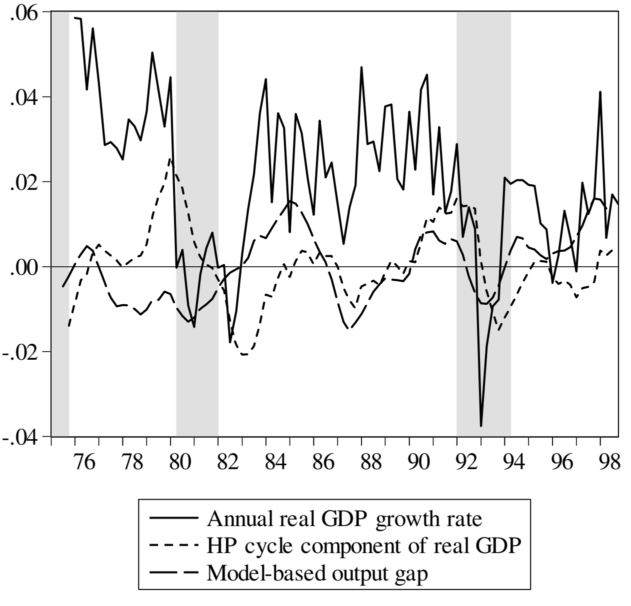
Notes: Indirect inference estimation with four observed variables (consumption share, inflation rate, interest rate and consumption growth rate), one lag in the auxiliary VAR model, and time series length multiplier 10. Coefficients without t-Statistics are not estimated but set *a priori*.

From the estimated model, the unobservable shocks and the output gap are uncovered using the Kalman filter. As suggested by Hamilton (1986), we run 2000 Monte Carlo simulations and draw the parameter vector from a multivariate normal distribution using the point estimates as mean vector and the estimated covariance matrix. The shocks and output gap, which we present in the next section, are 4-period centered moving averages of the means of the 2000 estimated state vectors.

4.2 Discussion of Empirical Results

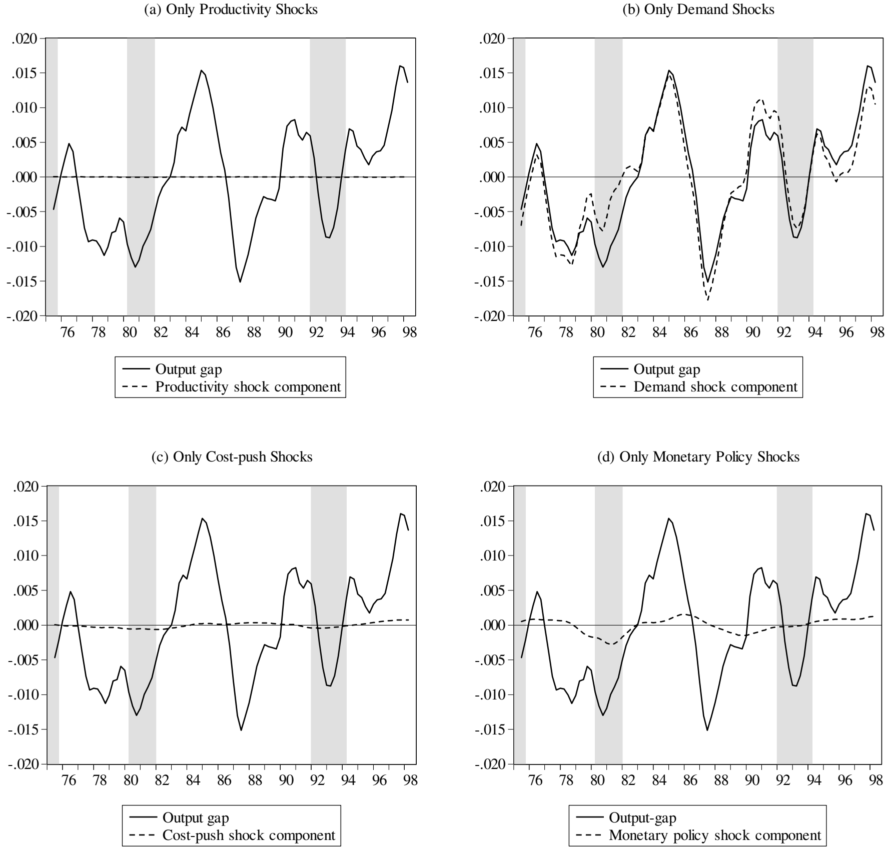
Output gap. The model-based output gap is shown together with the annual GDP growth rate and the HP-filtered GDP in figure 1 (actually, the figure shows 4-period centered moving averages of HP cycle and model-based output gap for illustrative purposes). The shaded areas in figure 1 represent recessions in Germany according to the business cycle classification by Heilemann and Münch (1999).

Figure 1: Model based output gap



The model-based output gap coincides very well with the business cycle classification of Heilemann and Münch (1999), while HP-filtered output shifts the 1980-82 recession to 1983. In this sense, we can confirm the statement of McCallum and Nelson (1999b) that the HP filter seems to be an inappropriate proxy for the output gap "because it does not properly reflect the influence of technology shocks". Additionally, it can be seen from figure 2 that the output gap is mainly driven by demand shocks. This figure is generated setting all shocks but one to zero, respectively.

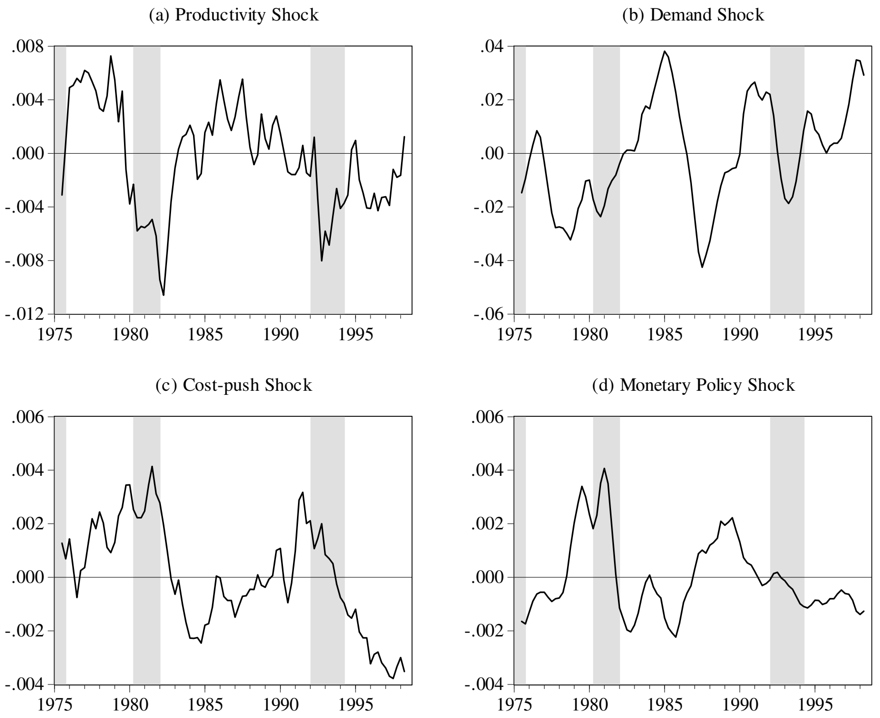
Figure 2: Output gap decomposition



The upper right figure shows how the output gap would have looked like if only the demand shock had been present, for example. It becomes clear that the productivity shock does not contribute to the explanation of the output-gap (see flat line in upper right panel of figure 2) because the estimated autocorrelation coefficient of this shock is very close to zero. Therefore, permanent productivity shocks lead to an immediate adjustment of consumption to the new flexible price output level. This is in contrast to findings of DeJong et al. (2000) for the US. Their results suggest that shocks to total factor productivity play an important role in driving cyclical activity.

Structural shocks. The estimated structural shocks are shown in figure 3.

Figure 3: Identified structural shocks



As figure 3 highlights negative productivity shocks and negative demand shocks have jointly contributed to the recessions in the 1980ies and in the 1990ies. Similar to the results of Weber (1996), we find that the economic downturn in the early eighties can largely be attributed to permanent productivity shocks and that the output expansion in 1990/91 can be attributed to stationary demand shocks. The cost push shock reveals the inflationary pressure in the late 1970ies due to oil price shocks and the inflationary pressure following the German reunification in the early 1990ies. Interestingly, panel (d) shows that monetary policy has been quite restrictive before and during the recession in the early 1980ies.

Business cycle accounting. The effects of the individual shocks on the observed variables and on the unobserved output gap can be summarized by correlation and relative variance statistics, which are provided in table 3.[3] The left part of the table shows variance shares, that is the variance of the corresponding variable if only one shock is active divided by the

[3] See Chari et al. (2007) for a detailed discussion of the business cycle accounting exercise using estimated structural models.

corresponding variance if all four shocks are present. The right part of the table shows the correlation coefficients of one-shock-simulations and all-shock-simulations.

Table 3: Business cycle accounting

Variable/ Shock	Variance Share				Contemporaneous Correlation			
	Technology shock	*GDP shock*	*Cost push shock*	*Monetary policy shock*	*Technology shock*	*GDP shock*	*Cost push shock*	*Monetary policy shock*
Consumption share	0.00	1.04	0.00	0.01	0.30	1.00	-0.19	-0.17
Output gap	0.00	0.93	0.00	0.01	-0.27	0.99	0.30	0.32
Inflation	0.00	0.01	1.02	0.00	-0.22	0.05	0.99	-0.35
Interest rate	0.00	0.40	0.14	1.09	-0.24	-0.17	0.66	0.83
Consumption growth	0.92	0.01	0.00	0.00	1.00	0.59	0.12	-0.26
GDP growth	1.30	0.78	0.00	0.00	0.66	0.28	0.10	-0.05

Our model specification suggests that output growth and consumption growth are primarily caused by persistent productivity shocks while fluctuations in consumption share and output gap can be mainly attributed to demand shocks. The inflation rate is not explained by the structural model because it is mainly driven by the cost-push shock. The interest rate is influenced by cost-push and interest rate shocks.

5 Conclusions

We have presented an estimated small New Keynesian macroeconomic model for Germany from 1975 to 1998. We have calculated a model-based output gap, which coincides very well with other business cycle fluctuation classifications. Additionally, we have identified the economic shocks, which have driven the German business cycle in the sample period and shown how much these shocks contribute to the actual behaviour of output gap and observed data like output and consumption growth rates, inflation rate and interest rate. Our findings suggest that business cycle fluctuations measured by the output gap are mainly driven by demand shocks. However, productivity shocks have substantial effects on potential output and therefore are a main driver for output and consumption growth. The model presented in this paper is highly stylized. Furthermore, the robustness of the results has not been checked systematically. However, it can already be stated that the model-based approach to business cycle accounting that we have used is an interesting tool for structural business cycle analysis. The improvement and extension of the analysis will be subject to further research.

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