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Determinants of Business Cycles in Small Scale Macroeconomic Models: The German Case

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Abstract

We identify measures of shocks to total factor productivity and preferences from two real business cycle models and subject them to Granger causality tests to see whether they can be considered exogenous to other plausible sources of the German business cycle. For the period 60.i to 89.iv no variable Granger causes the shock measures, and for the period 70.i to 01.iv, only M3 does. We attribute the latter result to the breaks in our time series associated with the German reunification in 1990 and the European Monetary Union in 1999. We, thus, find no evidence to reject the exogeneity of our shock measures. Our findings contrast with similar studies for other countries that question the exogeneity of either productivity or preference shocks.

Keywords Real Business Cycles, Solow Residual, Granger Causality

JEL Classification E32, O47

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I. Introduction

Small scale dynamic general equilibrium models have become the dominant tool of business cycle analysis. The driving force of these models are a few stochastic processes that mimic either demand or supply shocks that continually hit the economy. These shocks trigger intra- and intertemporal substitution between leisure, consumption, and asset holdings that cause patterns similar to those found in macroeconomic time series. If this story is a credible explanation of the business cycle, the various shock measures used should be exogenous in the sense that they are not themselves caused by other variables that one might regard as alternative driving forces of the cycle.

Among the most prominent shock measures is the Solow residual, i.e., that part of output growth which is not due to increased use of labor and capital. The seminal papers of Kydland and Prescott (1982) and Long and Plosser (1983) aim to show that a great part of observed output fluctuations is explained by shocks to total factor productivity approximated by the Solow residual. Subsequent papers cast doubt on the validity of this approach since they show that the Solow residual is Granger caused by real and monetary variables (Evans (1992) for the US, Cozier and Gupta (1993) for Canada, and Holland and Scott (1998) for the UK). Among the explanations for this lack of exogeneity are variable utilization rates of capital and labor (Burnside, Eichenbaum, and Rebelo (1993), Burnside and Eichenbaum (1996), Finn (1995), Paquet and Robidoux (2001)), and cyclical markups (Hornstein (1993), Rotemberg and Woodford (1992), and Hairault and Portier (1993)).

Holland and Scott (1998) introduce stochastic shifts of the marginal rate of substitution between leisure and consumption into an otherwise standard real business cycle model to capture demand shocks. Their measure of the preference shift parameter for the UK is Granger caused by the GDP deflator, the retail price index, and the nominal and real price of oil.

In this paper, we examine the issue of the exogeneity of technology and preference shocks for the German economy. We consider the period 1960 to 2001, divided into three subperiods for which reasonably consistent quarterly time series exist. The smallest sample covers the time period 76.i to 89.iv. We have chosen this period for the following reasons. Firstly, we want to exclude possible structural breaks associated with the German reunification in 1990. Secondly, considering the time between 1960 (from where onwards quarterly national accounts are available) and the mid nineteen seventies, there is evidence that the West German economy was catching up to its long-run growth path. However, the calibration of the model's parameters that are necessary to identify the technology and the preference shock rely on the steady-state assumption. Despite this problem, and to check the robustness of our results both with respect to the choice of the model's deep parameters and the period considered, we extend the sample to the period 60.i to 89.iv. Economic data for the post unification period are available from 1991.i onwards. They refer to the 1995 European System of National Accounts which differs in a number of respects from the former German System of National Accounts developed in the late 1950s. Thus, in addition to the break related to German unification, there are breaks in many major economic aggregates due to conceptual changes in national accounting. Data that are consistent to those from the post-unification era date back to 1970. Therefore, our third data set covers the period 70.i to 01.iv.

Using the Holland and Scott (1998) model as well as a more elaborate version allowing for oil price shocks, a variable utilization of capital, and a declining trend in working hours, we identify two different measures of the technology and preference shocks and test within an error correction framework their exogeneity with respect to government consumption, taxes, M1 and M3, short-term and long-term interest rates, exports, and the terms of trade. We conduct 161 different tests, 105 of which pertain to the two West German subsamples. Out of these 105 tests only 5 (less than the type I error) reject the null of no Granger causality. In the case of our third subsample, 70.i to 01.iv, we find evidence that all four of our shock measures are Granger caused by M3. However, this finding may be related to the jumps in this aggregate due to the German monetary union (effective on July 1, 1990), about two quarters before the jump in the national accounts, and the European monetary union (effective on January 1, 1999).

Different from the existing evidence for other countries, our results support the view that the German, and in particular the West German measures of technology and preference shocks may be regarded as driving forces of the business cycle in small scale models of economic fluctuations.

The remaining of the paper is structured as follows. The next section sets up the theoretical framework we use to identify our shock measures. In Section III, we derive the shocks from the data and test for Granger causality. Section IV concludes.

II. Theoretical Framework

1. A Basic Model

The basic real business cycle model with a technology and a preference shock consists of a representative household who solves at time t the following program:

$$\begin{aligned} &\max \quad E_t \sum_{s=0}^{\infty} \beta^s u(C_{t+s}, 1 - N_{t+s}, \theta_{t+s}), \qquad \beta \in (0,1) \\ &\text{subject to } K_{t+s+1} \leq (1-\delta)K_{t+s} + F(N_{t+s}, K_{t+s}, A_{t+s}) - C_{t+s}. \end{aligned} \tag{II.1}$$

Utility u at period $t+s$ depends upon consumption C_{t+s}, leisure $1-N_{t+s}$, and the realization of the preference shock θ_{t+s}. Expected life-time utility at time t is the discounted flow of utilities u with discount factor β^s attached to utility obtained s periods hence. Output is a function F of working hours N_{t+s}, capital services K_{t+s}, and the stochastic level of technological progress A_{t+s}. Future capital K_{t+s+1} is equal to the stock of capital inherited from the previous period $(1-\delta)K_{t+s}$, where $\delta \in [0,1]$ is the rate of depreciation, plus investment $F(\cdot) - C_{t+s}$.

Given representations of both the current-period utility function u and the production function F, the usual procedure is to compute measures of θ_t and A_t from actual data using the first order conditions of (II.1).

As usual, we parameterize $F(\cdot)$ as a constant-returns-to-scale Cobb-Douglas function

$$F(N_t, K_t, A_t) := B(A_t N_t)^\alpha K_t^{1-\alpha}, \quad \alpha \in (0,1), \quad B > 0, \tag{II.2}$$

where labor-augmenting technological progress A_t evolves according to

$$A_{t+1} = A_t e^{a+\epsilon_{t+1}^A}, \qquad a \geq 0, \quad \epsilon \sim N(0, \sigma^A). \tag{II.3}$$

To derive the preference shock, we specify u as

$$u(C_t, 1-N_t, \theta_t) := \frac{C_t^{1-\eta}(1-N_t)^{\theta_t(1-\eta)} - 1}{1-\eta}, \qquad \eta > 0. \tag{II.4}$$

The first order conditions for (II.1) with respect to consumption and leisure at time t imply

$$\theta_t = \alpha \frac{1-N_t}{N_t}\frac{Y_t}{C_t}. \tag{II.5}$$

Solving (II.2) for A_t provides

$$A_t = (Y_t/B)^{1/\alpha} K_t^{(\alpha-1)/\alpha} N_t^{-1}. \tag{II.6}$$

Equations (II.5) and (II.6) allow to derive the model's shocks from the national accounts. Before we proceed towards that goal, we develop a more elaborate version of this model that captures two distinctive features of the West German economy: Firstly, working hours per member of the work force have steadily declined since the nineteen sixties. Secondly, West Germany depends on energy imports.

2. A More Elaborate Model

To account for the decline in working hours, we follow Lucke (1997) and assume that the disutility of labor increases with the level of technological knowledge. Therefore, we measure leisure as $1 - A_t^\psi N_t$, with $\psi > 0$, in the household's utility function u.

We use the device developed by Finn (1995) to model the dependence on energy imports and assume that output of period t, Y_t, is produced according to the following production function:

$$Y_t = B(A_t N_t)^{\alpha}(v_t K_t)^{1-\alpha}, \quad \alpha \in (0,1), \quad B > 0, \tag{II.7}$$

where, as before, A_t is the level of labor-augmenting technical progress and N_t are working hours. Different from the basic model, we allow for less than full utilization of capital K_t and let v_t denote the respective utilization rate. The process that governs A_t is still given by (II.3).

Let W_t and R_t denote the real wage and the rental rate of capital services $v_t K_t$. Profit maximization on competitive markets implies:

$$W_t = \alpha \frac{Y_t}{N_t} = \alpha A_t B(A_t N_t)^{\alpha-1}(v_t K_t)^{1-\alpha}, \tag{II.8a}$$

$$R_t = (1-\alpha)\frac{Y_t}{v_t K_t} = (1-\alpha)B(A_t N_t)^{\alpha}(v_t K_t)^{-\alpha}. \tag{II.8b}$$

The household accumulates capital according to

$$K_{t+1} = (1-\delta(v_t))K_t + I_t \tag{II.9a}$$

$$\delta(v_t) := v_t^{\omega}/\omega, \quad \omega \geq 1, \tag{II.9b}$$

where I_t denotes the household's investment expenditures. The dependence of the rate of depreciation δ on the utilization rate of capital v_t captures the idea that wear and tear increase with a more intense use of the capital equipment. This assumption dates back to papers by Taubman and Wilkinson (1970) and Greenwood, Hercowitz, and Huffman (1988), and was also employed by Finn (1995) and by Burnside and Eichenbaum (1996) to account for factor hoarding over the business cycle.

To account for the influence of energy prices, we follow Finn (1995) and assume that the higher the capital utilization rate, the more energy Z_t per unit of capital K_t is required. Specifically, we postulate:

$$\frac{Z_t}{K_t} = v_t^{\gamma}/\gamma, \quad \gamma \geq 1. \tag{II.10}$$

The household spends its net income, i.e., wages $W_t N_t$ and capital rents $R_t v_t K_t$ less government taxes T_t, on energy imports $p_t Z_t$, consumption C_t, and investment I_t. Thus, its budget constraint is:

$$I_t + C_t \leq W_t N_t + R_t v_t K_t - T_t - p_t Z_t. \tag{II.11}$$

The household seeks time profiles for consumption and leisure that maximize

$$E_t \sum_{s=0}^{\infty} \beta^s \frac{C_{t+s}^{1-\eta}(1 - A_{t+s}^{\psi} N_{t+s})^{\theta_t(1-\eta)} - 1}{1-\eta}$$

subject to (II.9) and (II.11). The first order conditions for optimal time sequences imply:

$$\Lambda_t = C_t^{-\eta}(1 - A_t^{\psi} N_t)^{\theta_t(1-\eta)}, \tag{II.12a}$$

$$A_t^{-\psi} W_t \Lambda_t = \theta_t C_t^{1-\eta}(1 - A_t^{\psi} N_t)^{\theta_t(1-\eta)-1}, \tag{II.12b}$$

$$R_t = v_t^{\omega-1} + p_t v_t^{\gamma-1}, \tag{II.12c}$$

$$\Lambda_t = \beta E_t \Lambda_{t+1}\Big(1 - (v_{t+1}^{\omega}/\omega) - p_{t+1}(v_{t+1}^{\gamma}/\gamma) + R_{t+1} v_{t+1}\Big), \tag{II.12d}$$

where Λ_t is the shadow price of capital accumulation. According to (II.12a), this shadow price equals the marginal utility of consumption. (II.12b) states that the marginal disutility of an additional hour of work has to be compensated by the increase of utility derived from spending the extra income generated on consumption. Equation (II.12c) balances the marginal costs and benefits of changing the utilization rate of capital. The rate of change of the price of new capital is determined in equation (II.12d). It balances the current utility loss of saving one extra unit of output, Λ_t, with its discounted expected future utility gain, the latter being equal to the discounted expected utility increase from spending the gross return $1 - \delta(v_{t+1}) - p_{t+1}(Z_{t+1}/K_{t+1}) + r_{t+1} v_{t+1}$ on consumption in the next period.

We model government expenditures as a pure transfer of resources from the private to the public sector without any feed-back effects that would arise if they were considered an argument of either the household's utility function or the economy's production function. This transfer grows deterministically at the same rate as output increases in the long run, so that the government does not contribute to economic fluctuations. These assumptions can be summarized in the following equations:

$$G_t = T_t,$$
$$G_t = e^{g_Y t} G_0,$$

where g_Y is the growth rate of output on a balanced growth path, which is derived in the following section.

3. Dynamics

We want to calibrate the model's deep parameters from its implications for a deterministic balanced growth path. Our next task is, thus, to seek a transformation that yields new variables being constant on such a path. It is obvious from the utility function that $A_t^{\psi} N_t$ must be constant in the long run. Thus, we define $n_t := A_t^{\psi} N_t$. Furthermore, in the steady state both the capital-output ratio K_t/Y_t and the utilization rate of capital v_t should be constant. Thus, from equation (II.8b), the steady-state rental rate of capital R_t is constant. We can use this implication to look for an adequate transformation of the capital stock:

$$\begin{aligned} R_t &= (1-\alpha)B(A_t N_t)^{\alpha}(v_t K_t)^{-\alpha}, \\ &= (1-\alpha)B A_t^{\alpha(1-\psi)} n_t^{\alpha}(v_t K_t)^{-\alpha}. \end{aligned}$$

The last line tells us that ultimately the capital stock will grow at the rate of $g_K = e^{a(1-\psi)} - 1$. We use the transformation

$$k_t := \frac{K_t}{A_{t-1}^{1-\psi}},$$

which guarantees that the new variable is predetermined at the beginning of period t as a result of past realizations of the technology shock and past investment decisions. The equilibrium condition for the labor market (II.8a) may be written as

$$\begin{aligned} W_t &= \alpha B A_t^{\alpha+(1-\alpha)\psi} n_t^{\alpha-1}(v_t k_t)^{1-\alpha} A_{t-1}^{(1-\alpha)(1-\psi)}, \\ &= \alpha B A_t (A_t/A_{t-1})^{(\alpha-1)(1-\psi)} n_t^{\alpha-1}(v_t k_t)^{1-\alpha}, \end{aligned}$$

from which we see that $w_t := W_t/A_t$ is stationary. It is obvious from the household's budget constraint that in the long run consumption and government expenditures must grow at the same rate as the capital stock. Therefore, we define $c_t := C_t A_t^{\psi-1}$, $g_t := G_t A_t^{\psi-1}$ and derive the adequate transformation of the shadow price of new capital from equation (II.12a):

$$\lambda_t := \Lambda_t A_t^{\eta(1-\psi)} = \left(\frac{C_t}{A_t^{1-\psi}}\right)^{-\eta} (1-n_t)^{\theta_t(1-\eta)}.$$

Given these definitions, we combine equations (II.7), (II.8), (II.9), (II.11), and (II.12) and arrive at the following system of equations that governs the time paths of our transformed variables:

$$\lambda_t = c_t^{-\eta}(1-n_t)^{\theta_t(1-\eta)}, \tag{II.13a}$$

$$w_t = \theta_t \frac{c_t}{1-n_t}, \tag{II.13b}$$

$$w_t = \alpha B e^{(1-\alpha)(\psi-1)[a+\epsilon_{t-1}^A]} n_t^{\alpha-1}(v_t k_t)^{1-\alpha}, \tag{II.13c}$$

$$R_t = (1-\alpha) B e^{\alpha(1-\psi)[a+\epsilon_{t-1}^A]} n_t^{\alpha}(v_t k_t)^{-\alpha}, \tag{II.13d}$$

$$R_t = v_t^{\omega-1} + p_t v_t^{\gamma-1}, \tag{II.13e}$$

$$\begin{aligned} k_{t+1} = {} & B e^{(\alpha-1)(1-\psi)[a+\epsilon_{t-1}^A]} n_t^{\alpha}(v_t k_t)^{1-\alpha} \\ & + \Big(1 - (v_t^{\omega}/\omega) - p_t(v_t^{\psi}/\psi)\Big) e^{(\psi-1)[a+\epsilon_{t-1}^A]} k_t - c_t - g_t, \end{aligned} \tag{II.13f}$$

$$\lambda_t = \beta E_t e^{\eta(\psi-1)(a+\epsilon_{t+1}^A)} \lambda_{t+1} \left(1 - (v_{t+1}^{\omega}/\omega) - p_{t+1}(v_{t+1}^{\gamma}/\gamma) + v_{t+1}R_{t+1}\right). \tag{II.13g}$$

We get the deterministic counterpart of our model by replacing the technology shock, the preference shock, and the energy-price shock by their expected values of e^a, θ and p, respectively. This permits us to omit the expectation operator. If we further drop time indices, the system of equations (II.13) determines the model's long-run equilibrium. We use these relations to calibrate the model to German data.

If $n_t := A_t^{\psi} N_t$ is constant and $\psi > 0$, hours per capita decline at the rate $g_N = e^{-a\psi} - 1$ and output grows at the rate $g_Y = e^{a(1-\psi)} - 1$. Thus, we can use the long-run rate of output growth g_Y and the rate of change of hours per capita g_N to infer ψ and a from

$$\begin{aligned} \ln(1+g_Y) &= a(1-\psi), \\ \ln(1+g_N) &= -a\psi. \end{aligned} \tag{II.14}$$

We set the long-run rate of capital depreciation δ equal to the average rate of capital depreciation and compute this rate from quarterly data of depreciation and the capital stock. We construct the latter from yearly data of the capital stock and quarterly data of net investment expenditures via the perpetual inventory method.

The Euler equation for the price of new capital

$$1 = \beta e^{-\eta(1-\psi)a} \underbrace{(1 - \delta - p(Z/K) + Rv)}_{q} \tag{II.15}$$

provides two options to infer the magnitude of the discount factor β. Given information on the long-run gross rate of return on equities q and the intertemporal elasticity of substitution $1/\eta$, we may compute β from

$$\beta = \frac{e^{\eta(1-\psi)a}}{q}. \tag{II.16}$$

Alternatively, using the stationary version of (II.8b), equation (II.15) may also be written as

$$1 = \beta e^{-\eta(1-\psi)a}\left(1 - \delta - \left[\frac{pZ}{Y} - (1-\alpha)\right]\frac{Y}{K}\right), \tag{II.17}$$

which allows us to derive β from the capital-output ratio K/Y, the fraction of output spent on energy imports (pZ/Y), and the elasticity of production with respect to labor α. As usual, the latter parameter is set equal to the long-run wage share.

We derive point estimates of γ, ω, and v from the fraction of output spent on energy imports $\zeta := (pZ/Y)$, the rate of capital depreciation δ, and the capital-output ratio K/Y. Notice that equations (II.13d) and (II.13e) imply

$$Rv = v^{\omega} + pv^{\gamma} = (1-\alpha)\frac{Y}{K},$$

which we arrange to read

$$\underbrace{\frac{pv^{\gamma}}{\gamma}\frac{K}{Y}}_{\zeta} = \frac{1-\alpha}{\gamma} - \frac{\omega}{\gamma}\frac{K}{Y}\underbrace{\frac{v^{\omega}}{\omega}}_{\delta}.$$

Thus, together with the definitions in (II.9b) and (II.10), the following system of equations jointly determines ω, γ, and v:

$$\begin{aligned} \zeta &= \frac{1-\alpha}{\gamma} - \frac{\omega}{\gamma}\frac{K}{Y}\delta, \\ \delta &= \frac{v^{\omega}}{\omega}, \\ \zeta\frac{Y}{K} &= p\frac{v^{\gamma}}{\gamma}, \end{aligned} \tag{II.18}$$

where p is the average relative price of imported energy.

III. Productivity and Preference Shocks

1. Identification of the Shocks

Given the model's deep parameters, we are able to construct the productivity and preference shocks from the model's equations and published data.

Equations (II.8b) and (II.12c) imply:

$$v_t^{\omega} + p_t v_t^{\gamma} = (1-\alpha)\frac{Y_t}{K_t}. \tag{III.1}$$

Together with the law for capital accumulation (II.9) and an initial value of the capital stock, this equation implies an empirical series for the utilization rate of capital v_t from published data on output Y_t, the relative price of imported energy p_t, and investment expenditures I_t. Given the series on v_t and K_t, we derive the level of technical progress from the production function using published data on working hours and output:

$$A_t = (Y_t/B)^{1/\alpha}(v_t K_t)^{(\alpha-1)/\alpha} N_t^{-1}. \tag{III.2}$$

We use the value of B to normalize $A_{t=1} \equiv 1$. Given this series we construct $n_t = A_t^{\psi} N_t$ and compute the preference shock from

$$\theta_t = \alpha \frac{1-n_t}{n_t} \frac{Y_t}{C_t} \tag{III.3}$$

using data on output and consumption. These equations are the counterparts to the simpler shock measures given in (II.6) and (II.5).

2. Calibration

We estimate the deep parameters of the model for three subperiods to check the robustness of our results. The period that fits the theoretical assumptions closest covers 1976.i to 1989.iv. Between 1960 and the mid nineteen seventies, the West German consumption share in output steadily increased, as it may happen along the transition path to a steady state equilibrium. On such a path, the growth rate of per-capita output exceeds the growth rate of labor augmenting technical progress and the average productivity of capital as well as the real interest rate are above their long-run values. Thus, estimates of these parameters from time series averages during transition periods are biased upwards, and we expect more reliable estimates if we restrict attention to the period after 76.i. Data after 1990 reflect the economic consequences of the German reunification, which was without doubt a major economic shock that put the German economy on a new transition path, raising similar estimation problems. The drawback from this restriction is obvious: our tests may suffer from low power due to a lack of degree of freedoms. Therefore, we extend our sample to cover the period 60.i to 89.iv, the longest period for which quarterly economic data for West Germany are available. Due to changes in the German system of national accounts in the mid nineteen nineties we are currently not able to extend the sample further to cover 60.i to 01.iv. Data consistent with the new European system of national accounts only date back to 70.i. Therefore, our third subsample covers the period 70.i to 01.iv. In the following, we sketch the parameter selection for the first subsample and summarize the results together with those for the other subsamples in Table III.1.

To take account of the representative agent character of our model, we use per-capita data on output, consumption, investment, capital, and working hours. If not otherwise mentioned, we use seasonally-adjusted time series from the database provided by the German Institute of Economic Research (DIW). Our measure of output is the gross domestic product per capita at factor prices, which grew at an average quarterly rate of $g_Y = 0.47\%$. Hours per capita declined at an average quarterly rate of $g_N = 0.08\%$. Using (II.14) we find that the average quarterly growth rate of labor-augmenting technical progress is $a = 0.0055$ and that the interaction parameter between the disutility of labor and the level of technological progress is $\psi = 0.144$.

We combine the yearly data of the capital stock provided by the German Statistical Office (Statistisches Bundesamt) and quarterly data on depreciation and gross investment to compute a quarterly series of the capital stock. Let $\bar{K}_j$ and K_t denote the stock of capital at the beginning of year $j = 0, 1, ..., 13$ and at the beginning of quarter $t = 1, 2, ..., 56$, respectively. For $t = 4j + 1$, we set $K_t = \bar{K}_j$, and for $t = 4j + 1 + s,\ s = 1, 2, 3$, we compute K_t from

$$K_{t+1} = K_t + (I_t - D_t)\frac{\bar{K}_{j+1} - \bar{K}_j}{\sum_{i=1}^{4}(I_{4j+i} - D_{4j+i})},$$

where I_t and D_t are gross investment and depreciation of quarter t. Given this measure of capital we set δ equal to the average of D_t/K_t, which yields $\delta = 0.0108$.

The average expenditure on raw-oil imports as a fraction of the gross domestic product at factor prices is $\zeta = 0.0215$. The wage share in the gross domestic product at factor prices is $\alpha = 0.72$. We derived this figure assuming that the wage income of a self-employed person equals the average wage per employee.

To circumvent assumptions about the coefficient of relative risk aversion and the adequate measure of the long-run return on capital, we use the average capital-output ratio $k/y = 0.0774$ in (II.18) to infer γ, ω and v. This yields the long-run utilization rate of capital $v = 0.081$, the energy consumption parameter $\gamma = 2.36$, and the wear-and-tear parameter $\omega = 1.61$.

We used the same procedure to find the parameters for the period 60.i to 89.iv. Our estimates of the trend in output and working hours (both per capita) for the third period assume a sudden shift of the trend line in the first quarter of 1991 but unchanged growth rates. Table III.1 summarizes our choice of parameter values. The wage share α and the rate of depreciation δ are almost the same in all three subperiods. As expected, the growth rate of labor augmenting technical progress a and capital productivity Y/K are larger in the second and third subperiod. The negative trend in per-capita working hours was more pronounced in the second period resulting in a much larger value of ψ. Our estimate of this parameter for the

Table III.1:
Parameter Choice

Parameter	Periods		
	76.i to 89.iv	60.i to 89.iv	70.i to 01.iv
a	0.0055	0.0095	0.0067
ν	0.1436	0.2934	0.2485
Y/K	0.0774	0.0825	0.0075
α	0.7235	0.7248	0.7136
δ	0.0108	0.0105	0.0117
ζ	0.0186	0.0215	0.0155

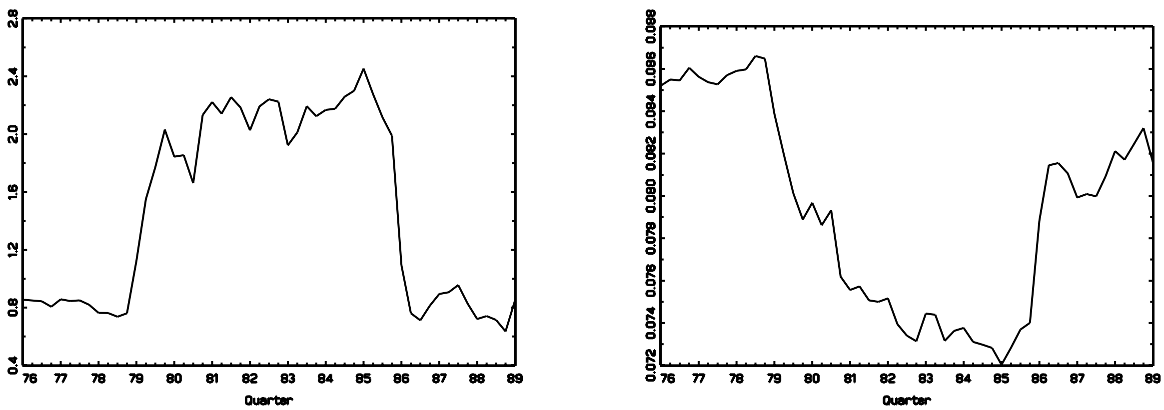
third period is of comparable size, but this may reflect the sharp increase in unemployment in the new federal states due to the restructuring of the former centrally planned economy.

3. Shock Measures

We are now able to construct our measures of productivity and preference shocks. We illustrate the main differences between our benchmark model and the more elaborate model with respect to the first subperiod. The same findings apply to the second and third subsample.

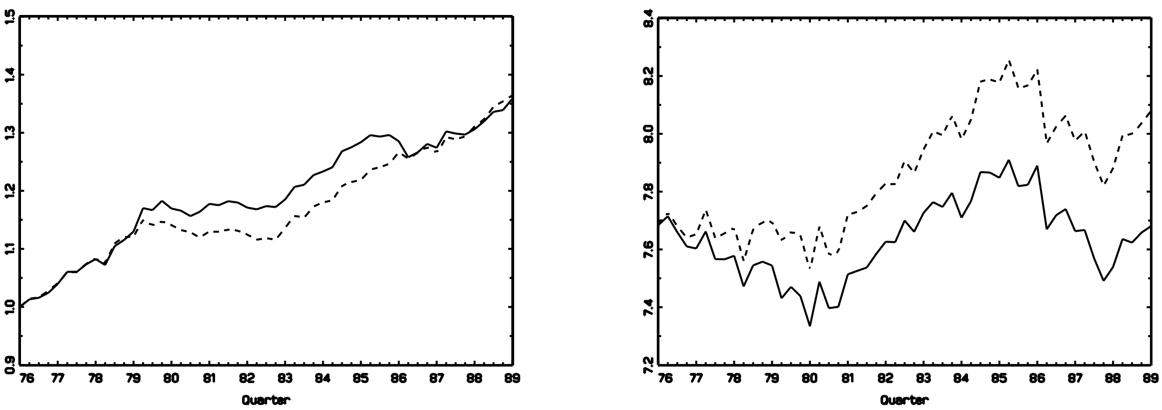
Figure III.1 displays the relative price of oil as given by the oil price index compiled at the Hamburg Institute of International Economics (HWWA). As can be seen from the right panel of Figure III.1, the price increase in the nineteen eighties let the utilization rate of capital drop sharply. As a consequence, the traditional method to compute the Solow Residual from

Figure III.1: Oil Price Shocks and Utilization Rate of Capital



(II.6) systematically overestimates the productivity shocks in the first half of the nineteen eighties and underestimates them in the second half. This can be seen from the left panel of Figure III.2, where the dashed line depicts the usual measure of the Solow Residual. The solid line shows the productivity shock computed from (III.2). The right panel of Figure III.2 displays the preference shock. If measured by (II.5), the decline in working hours shows up in an upward sloping trend of the dashed line. The solid line represents the preference shock measure from (III.3). We will refer to the shocks from the basic model as model-one shocks and to those from the more elaborate model as model-two shocks.

Figure III.2: Productivity and Preference Shocks: 76.i to 89.iv

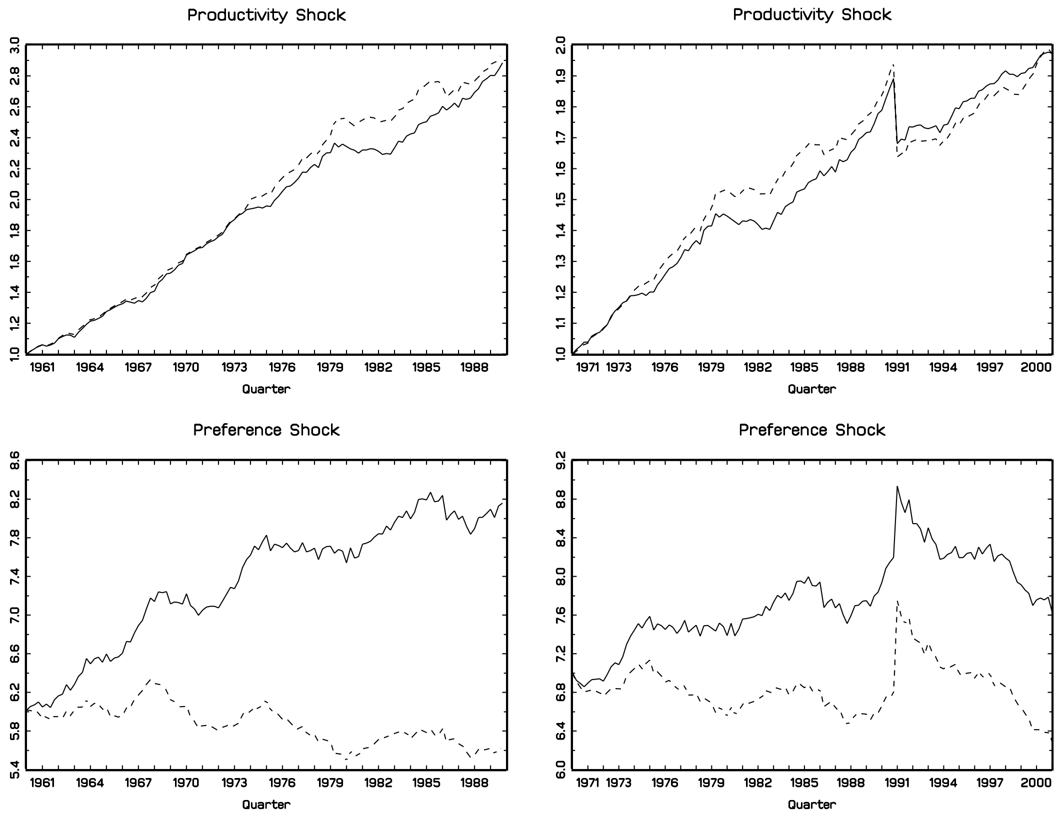


More or less the same picture emerges for the period 60.i to 89.iv shocks depicted in the left panel of Figure III.3. The reunification shock appears as a sudden decrease in the level of technical progress, and the associated massive rise of unemployment is attributed to a large increase in the disutility of labor (see the right panel of Figure III.3).

4. Granger Causality Tests

Exogenous Variables We investigate the exogeneity of our measures of the productivity and the preference shock in the framework of Granger causality tests. If these shocks are indeed the driving forces of the business cycle, it should be impossible to predict them from past realizations of other variables that are also exogenous to the model. Since we have assumed that government expenditures and, hence, tax revenues grow at a constant rate, we include measures of both variables in the set of plausible driving forces of the German business cycle. We capture monetary shocks with a narrow (M1) and a broad (M3) measure of money supply, as well as with a short-term and a long-term nominal interest rate. Exports, the terms of trade, and the price of oil are used to indicate demand and supply side shocks that originate in the world market. Like our shocks, they are either upward trending or display a highly persistent behavior (see Figure A.1 in the Appendix). Before we can proceed with

Figure III.3: Productivity and Preference Shocks, 60.i to 89.iv and 70.i to 01.iv



running regressions, we must determine the nature of this non-stationarity.

Unit Roots Tests We report the results of various unit roots test in Tables A.1 to A.3 in the Appendix. For the first and second subperiod we computed the augmented Dickey-Fuller t-statistic, the Phillips-Perron Z_t statistic as well as the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) statistic. Taking into account the break in 1991, we used Perron's extension of the ADF-test for the third subperiod.

There is only one variable where the unit-root assumption seems doubtful. For both the first and the second subperiod, the ADF-t-statistic rejects the unit root for the short-term interest rate, whereas the KPSS-statistic is not able to reject the converse null of stationarity. For the period 70.i to 01.iv, a unit root in the short-term interest rate is rejected at the 10 percent level. For the sake of a unified treatment, we consider the short-term interest rate I(1), too. The tests are not able to reject the unit-root assumption in the case of our second measure of the preference shock, which, by construction, should be stationary. Since it is well known that unit-root tests have small power against the alternative of a nearly integrated process, this finding should come as no surprise. We follow the recommendation of Banerjee et al. (1993:95) and treat this case as I(1) rather than as I(0).

Estimation Framework Under this proposition, we need to check whether variables that enter in a bivariate or multivariate vector autoregression (VAR) are cointegrated. If so, the adequate framework to pursue Granger causality tests is the following autoregressive vector error correction (VEC) model:

$$\begin{bmatrix} \Delta x_t \\ \Delta \mathbf{z}_t \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix} + \begin{bmatrix} A_{11}(L) & A_{12}(L) \\ A_{21}(L) & A_{22}(L) \end{bmatrix} \begin{bmatrix} \Delta x_{t-1} \\ \Delta \mathbf{z}_{t-1} \end{bmatrix} + \begin{bmatrix} \alpha_1(x_{t-1} - \beta_1 \mathbf{z}_{t-1}) \\ \alpha_2(x_{t-1} - \beta_2 \mathbf{z}_{t-1}) \end{bmatrix} \tag{III.4}$$

Here x_t is one of our shock measures and $\mathbf{z}_t$ is a subset of the variables that we consider to Granger cause the respective shock measure. The symbol Δ denotes first differences, A_{11} and A_{21} are polynomials in the lag operator L, whereas A_{12} and A_{22} are matrix polynomials in L that conform to the size of the vector $\mathbf{z}_t$. If the variables x_t and $\mathbf{z}_t$ are cointegrated, the expressions $(x_{t-1} - \beta_1 \mathbf{z}_{t-1})$ and $(x_{t-1} - \beta_2 \mathbf{z}_{t-1})$ capture deviations of the variables from their long-run equilibrium.

In this setting, the variables in $\mathbf{z}_t$ jointly Granger cause the shock measure x_t if the coefficients of A_{12} are significantly different from zero. We follow Holland and Scott (1998) and do not test whether the matrix α_1 is different from zero. The error correction term in the first equation captures the propagation of shocks but not their origin. Consider, e.g., a negative preference shock that temporarily lowers output growth. When tax revenues are tied to output, government expenditures will also fall below their trend path and help to predict future output growth.

Without cointegration, we have to drop the error correction term and estimate the VAR in first differences.

Cointegration Tests We use the Johansen (1988, 1992) cointegration test. To select the appropriate VAR order, we use the Akaike (AIC) and the Hannan-Quinn (HQ) information criteria.[1] We allowed for at most 8 lags in levels. We report our results for the first two subperiods in Tables A.4 and A.5 in the Appendix. There are a number of instances where either the trace or the maximum eigenvalue statistic (or even both) indicate two cointegrating relations at the five percent level of significance. Since this contrasts with our unit root tests, we accepted this conclusion only if both the trace and the maximum eigenvalue statistic

[1]For a definition of these statistics in the framework of vector autoregressive models see, e.g., Lütkepohl (1991), equations (4.3.2) and (4.3.8).

exceed the one percent critical value. This occurs in four out of a total of 105 cointegration tests we performed for the first and second subperiod. In these cases we estimated a VAR in levels including a linear time trend.

Cointegration tests for the third subperiod must deal with the problem that most of our time series display a marked break in the first quarter in 1991. If we disregard this break, the tests are not able to reject the null of no cointegration, except in a few cases. When we include a dummy variable that accounts for the break, the critical values of the Johansen test are strictly speaking not applicable. If we ignore this problem and take the critical values as indicative of cointegration, we find evidence for one cointegrating relation in about two-thirds of the tests performed (see Table A.6 in the Appendix). To circumvent this problem we performed Grange causality test for both first differences and levels. In the latter case we assumed one cointegrating relation.

Results of the Causality Tests Table III.2 presents the results of the bivariate Granger causality tests for the period 76.i to 89.iv. If the lag length criteria arrive at different conclusion about the number of lags q in the VAR in levels, we performed the test for both lag lengths. In the case of $q = 1$, neither the VEC(1) nor the corresponding VAR(0) in differences includes lagged differences, and no variable is able to Granger cause the respective other variable. We marked these instances with a dot.

There are two instances out of a total of 54 tests where we have to accept Granger causality: the model-one Solow residual is Granger caused by government expenditures (at $q = 8$) and by taxes (also at $q = 8$). Since the productivity shock is unable to predict government expenditures (the p–value for this null is 0.71), causality seems indeed to run from government expenditures to the productivity shock. In the case of taxes, causality is mutual. Yet, in VARs with a smaller order we are unable to reject the null in either case. None of our model-two shocks seems to be Granger caused by the variables listed in the left column of Table A.6.

It may well be that these tests suffer from low power. Our time series are rather short (56 observations each) and in many instances the required lag length is considerable so that there are few degrees of freedom. This is one reason to extend the observation period back to the first quarter of 1960. Table III.3 presents the outcome of the Granger causality test for this larger data set (120 observations in each series).

Here we run 51 different tests, 3 of which reject our null. The model-one productivity shock is Granger caused by the long-term interest rate at a lag length of $q = 6$, the model-two productivity shock by M3 at $q = 6$ (which is the lag length chosen by both the AIC and the HQ criterium), and the model-two preference shock by the terms of trade at $q = 6$ (again, the common lag length of the AIC and HQ criterium).

Table III.2:
Bivariate Granger Causality Tests 76.i-89.iv

Model-One Shock Measures

Variable	Productivity						Preferences					
	AIC			HQ			AIC			HQ		
	q	r	p	q	r	p	q	r	p	q	r	p
Government Expenditures	8	0	0.00	1	0	.	5	0	0.46	5	0	0.46
Taxes	8	0	0.04	5	0	0.20	4	0	0.29	1	0	.
M1	8	1	0.56	1	0	.	4	0	0.77	1	0	.
M3	8	1	0.43	5	0	0.58	5	0	0.37	5	0	0.37
Short-Term Interest Rate	5	0	0.18	5	0	0.18	2	0	0.29	2	0	0.29
Long-Term Interest Rate	5	0	0.42	1	0	.	3	0	0.81	1	0	.
Exports	5	0	0.65	5	0	0.65	8	0	0.73	2	0	0.38
Terms of Trade	6	0	0.62	6	0	0.62	6	0	0.54	5	0	0.33
Oil Price	5	0	0.81	2	0	0.44	4	0	0.70	2	0	0.25

Model-Two Shock Measures

Variable	Productivity						Preferences					
	AIC			HQ			AIC			HQ		
	q	r	p	q	r	p	q	r	p	q	r	p
Government Expenditures	1	0	.	1	0	.	8	1	0.33	5	0	0.48
Taxes	5	0	0.43	1	0	.	4	0	0.15	1	0	.
M1	1	1	.	1	1	.	4	0	0.45	1	0	.
M3	8	1	0.40	8	1	0.40	5	0	0.16	5	0	0.16
Short-Term Interest Rate	5	0	0.33	5	0	0.33	2	0	0.24	2	0	0.24
Long-Term Interest Rate	1	0	.	1	0	.	3	0	0.84	1	0	.
Exports	5	0	0.99	1	0	.	8	0	0.74	2	0	0.29
Terms of Trade	6	0	0.77	6	0	0.77	6	0	0.27	5	1	0.31

Notes:
AIC: Lag length selected according to Akaike's information criterium,
HQ: lag length selected according to Hannan-Quinn's information criterium,
q: number of lags considered,
r: number of cointegration relations, where r=2 indicates that we run the regression in levels,
p: marginal level of significance for the null that the shock measure is not Granger caused by the variable in column 1.

Considering both subsamples together we performed 105 different tests, each at the five percent level. Therefore, we can expect that on average we will get about five rejections of the null despite it being true. It is save to conclude that for the West German economy between 60.i and 89.iv the measures we have identified may be regarded as exogenous driving forces of small scale macroeconomic models, as the ones we have specified in model one and model two.

Turning to our third subperiod this conclusion seems less robust, at least at first glance.

Table III.3:
Bivariate Granger Causality Tests 60.i-89.iv

Model-One Shock Measures

Variable	Productivity						Preferences					
	AIC			HQ			AIC			HQ		
	q	r	p	q	r	p	q	r	p	q	r	p
Government Expenditures	7	1	0.32	5	1	0.33	5	0	0.34	1	1	.
Taxes	6	1	0.05	1	2	.	4	0	0.31	1	0	.
M1	6	0	0.13	6	0	0.13	7	0	0.86	6	0	0.80
M3	6	0	0.27	6	0	0.27	8	2	0.31	6	0	0.95
Short-Term Interest Rate	6	0	0.09	5	0	0.44	5	1	0.77	5	1	0.77
Long-Term Interest Rate	6	0	0.04	5	0	0.23	4	0	0.42	2	0	0.25
Exports	6	0	0.51	6	0	0.51	6	0	0.27	5	0	0.57
Terms of Trade	6	0	0.44	6	0	0.44	6	0	0.14	6	0	0.14
Oil Price	5	1	0.95	2	1	0.73	4	0	0.64	2	0	0.11

Model-Two Shock Measures

Variable	Productivity						Preferences					
	AIC			HQ			AIC			HQ		
	q	r	p	q	r	p	q	r	p	q	r	p
Government Expenditures	8	2	0.30	1	2	.	5	0	0.61	1	0	.
Taxes	5	1	0.72	1	2	.	4	0	0.39	4	0	0.39
M1	6	0	0.35	6	0	0.35	6	1	0.40	6	1	0.40
M3	6	0	0.03	6	0	0.03	6	0	0.77	6	0	0.77
Short-Term Interest Rate	5	0	0.66	5	0	0.66	5	1	0.44	5	1	0.44
Long-Term Interest Rate	6	0	0.18	2	0	0.81	4	0	0.23	4	0	0.23
Exports	5	0	0.92	5	0	0.92	6	0	0.39	5	0	0.32
Terms of Trade	6	0	0.09	6	0	0.09	6	0	0.03	6	0	0.03

Notes:
AIC: Lag length selected according to Akaike's information criterium,
HQ: lag length selected according to Hannan-Quinn's information criterium,
q: number of lags considered,
r: number of cointegration relations, where r=2 indicates that we run the regression in levels,
p: marginal level of significance for the null that the shock measure is not Granger caused by the variable in column 1.

According to Table III.4, the model-one preference shock is Granger caused by exports at $q = 8$, and by the oil price at both lag lengths considered. We find the latter result also in the error-correction framework presented in Table III.5 but not the first one. Less robust are also other instances of Granger causality since they emerge either in the error-correction framework or in the VAR in differences but not in both sets of tests. For instance, the long-term interest rate Granger causes the model-two preference shock in the VAR(4) but neither in the VAR(1) nor in the VECs. Government expenditures Grange cause both the model-one

Table III.4:
Bivariate Granger Causality Tests 70.i-01.iv: First Differences

Model-One Shock Measures

Variable	Productivity				Preferences			
	AIC		HQ		AIC		HQ	
	q	*p*	*q*	*p*	*q*	*p*	*q*	*p*
Government Expenditures	8	0.52	1	0.17	8	0.37	8	0.37
Taxes	4	0.09	0	.	4	0.56	4	0.56
M1	2	0.00	2	0.00	3	0.00	3	0.00
M3	2	0.00	2	0.00	3	0.00	3	0.00
Short-Term Interest Rate	1	0.54	1	0.54	3	0.92	1	0.66
Long-Term Interest Rate	1	0.57	1	0.57	4	0.09	1	0.16
Exports	8	0.92	4	0.84	8	0.02	4	0.17
Terms of Trade	8	0.05	1	0.52	8	0.44	8	0.44
Oil Price	5	0.31	1	0.45	5	0.00	4	0.00

Model-Two Shock Measures

Variable	Productivity				Preferences			
	AIC		HQ		AIC		HQ	
	q	*p*	*q*	*p*	*q*	*p*	*q*	*p*
Government Expenditures	8	0.33	1	0.17	8	0.08	2	0.44
Taxes	4	0.07	0	.	4	0.30	0	.
M1	2	0.00	2	0.00	4	0.00	3	0.00
M3	3	0.00	2	0.00	3	0.00	2	0.00
Short-Term Interest Rate	1	0.46	1	0.46	1	0.57	1	0.57
Long-Term Interest Rate	1	0.66	1	0.66	4	0.04	1	0.36
Exports	8	0.87	4	0.65	8	0.03	4	0.09
Terms of Trade	8	0.05	1	0.94	8	0.21	1	0.17

Notes:
AIC: Lag length selected according to the Akaike information criterium,
HQ: lag length selected according to the Hannan-Quinn information criterium,
q: number of lags considered,
p: marginal level of significance for the null that the shock measure is not Granger caused by the variable in column 1.

and the model-two productivity shock in the error-correction framework but not in the VARs in first differences.

Most obvious, however, is that all four of our shock measures are Granger caused by M1 and M3 according to both kinds of tests. When we consider three dimensional VARs which include both M1 and M3 and allow for one cointegrating relation, we cannot reject that M1 has no effect on either one of our four shocks (see Table A.7 in the Appendix). Furthermore, we are not able to reject the null that our shocks do not Granger cause M3. Thus, it seems that causality runs from M3 to the shocks. Given that there is no convincing

Table III.5:
Bivariate Granger Causality Tests 70.i-01.iv: Error Correction, r=1

Model-One Shock Measures

Variable	Productivity				Preferences			
	AIC		HQ		AIC		HQ	
	q	*p*	*q*	*p*	*q*	*p*	*q*	*p*
Government Expenditures	7	0.02	4	0.01	5	0.26	1	.
Taxes	2	0.45	2	0.45	8	0.51	1	.
M1	6	0.00	3	0.00	4	0.00	4	0.00
M3	6	0.00	3	0.00	4	0.00	4	0.00
Short-Term Interest Rate	2	0.93	2	0.93	5	0.79	2	0.85
Long-Term Interest Rate	2	0.18	2	0.18	4	0.41	2	0.27
Exports	5	0.35	5	0.35	5	0.30	5	0.30
Terms of Trade	6	0.95	2	0.84	6	0.37	6	0.37
Oil Price	6	0.61	2	0.31	6	0.01	5	0.00

Model-Two Shock Measures

Variable	Productivity				Preferences			
	AIC		HQ		AIC		HQ	
	q	*p*	*q*	*p*	*q*	*p*	*q*	*p*
Government Expenditures	5	0.00	4	0.00	7	0.01	2	0.61
Taxes	6	0.34	2	0.78	8	0.64	1	.
M1	3	0.00	3	0.00	4	0.00	4	0.00
M3	3	0.00	3	0.00	4	0.00	4	0.00
Short-Term Interest Rate	2	0.83	2	0.83	2	0.97	2	0.97
Long-Term Interest Rate	2	0.25	2	0.25	4	0.71	2	0.63
Exports	5	0.03	5	0.03	5	0.28	5	0.28
Terms of Trade	7	0.20	2	0.70	6	0.37	2	0.21

Notes:
AIC: Lag length selected according to the Akaike information criterium,
HQ: lag length selected according to the Hannan-Quinn information criterium,
q: number of lags considered,
p: marginal level of significance for the null that the shock measure is not Granger caused by the variable in column 1.

evidence for this finding in the West German data, we attribute this outcome to the structural breaks associated with both the German unification and the introduction of the European monetary union. Indeed, since the German monetary union became effective on July 1, 1990, M3 started to increase in 91.ii whereas our shock measures display their breaks two quarters later. However, we were not successful in controlling for this jump using a second dummy variable. Nevertheless, we hesitate to conclude that our shock measures reflect signs of 'regular' monetary policy shocks as opposed to those related to the changes in the institutional framework.

IV. Conclusion

The plausibility of small scale dynamic general equilibrium models of the business cycle driven by shocks to productivity and preferences depends upon whether or not these shocks can be considered exogenous with respect to other possible shock measures such as government expenditures, tax rates, money supply, interest rates, foreign demand, or world market prices. We consider this question with respect to the West German and German economy within the framework of two models. Model one is a standard real business cycle model whereas model two allows for variable capital utilization and the declining trend in West German working hours per capita. We use these models to identify shocks to total factor productivity and the marginal rate of substitution between leisure and consumption for three periods: 76.i to 89.iv, 60.i to 89.iv and 70.i to 01.iv. The first subperiod fits our theoretical assumptions closest but has relatively few observations. The related shortage of degrees of freedom for our econometric tests is not shared by our second subsample. While covering the more recent German economic history, the third subperiod suffers from the breaks in most economic time series that arise from the German reunification and from the introduction of the European monetary union.

For the West German economy, i.e., during the period 60.i to 89.iv, our Granger causality tests support the exogeneity of our shock measures. This is reflected in the fact that only 5 out of a total of 105 different tests reject the null of Granger causality at the five percent level of significance. This is less than the type I error.

The results for the more recent period 70.i to 01.iv are less favorable. We find more instances of Granger causality. However, except for the monetary aggregates M1 and M3, only one instance (the oil price causes the model-one preference shock) is robust to different specifications with respect to the lag length and the number of cointegrating relations. M1 and M3 appear to Grange cause all of our shock measures independent of the specification of the vector autoregressive models (VARs). Three-dimensional VARs with M1, M3, and the respective shock measure reveal that the ultimate influence comes from M3. Considering that the break in this series predates the break in our shock measures, we are not fully convinced by this result.

Appendix

Figure A.1: Time Paths of Test Variables

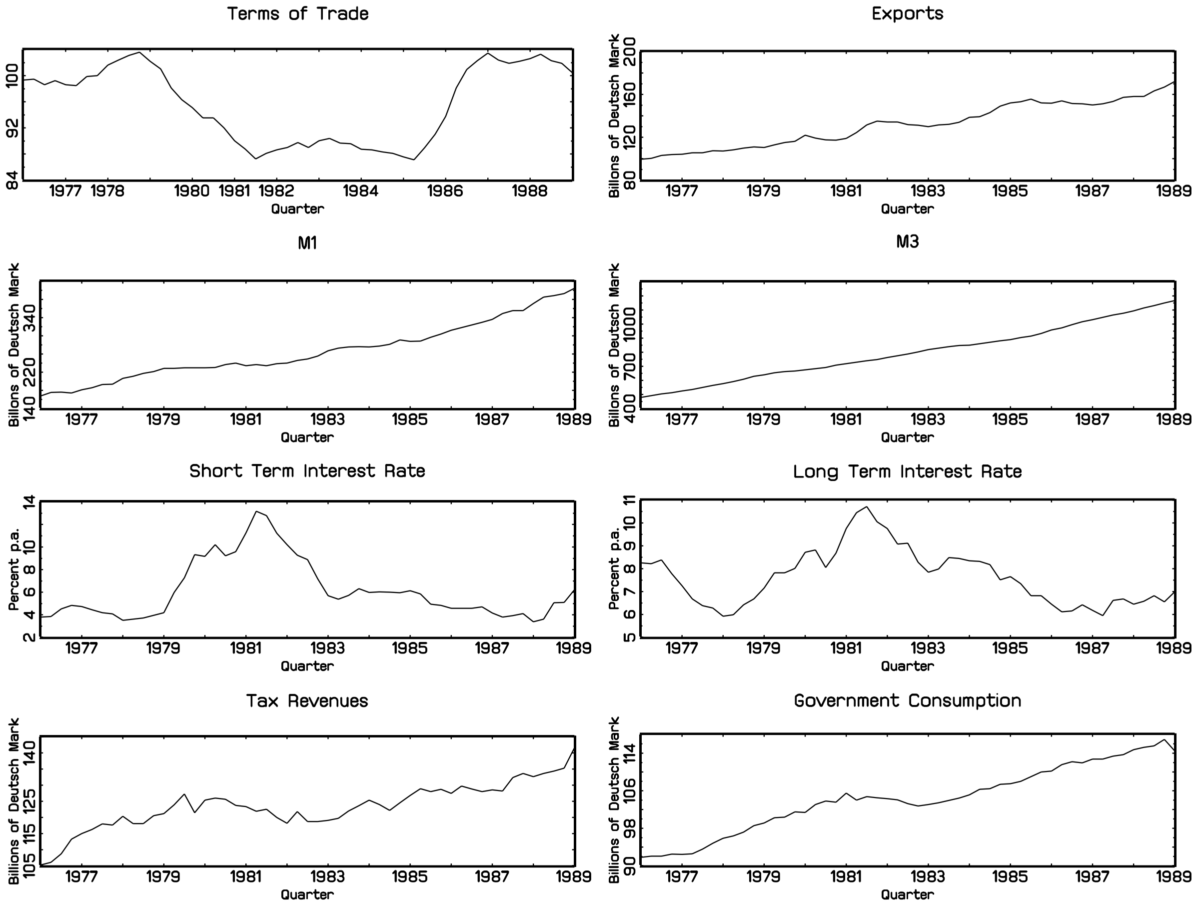


Table A.1:
Unit Root Tests 76.i-89.iv

Variable	Levels			First Differences	
	ADF	PP	KPSS	ADF	PP
Productivity Shock (1)	-1.449	-1.817	0.118	-2.958^{**}	-8.680^{***}
Productivity Shock (2)	-3.676^{**}	-2.522	0.105	-3.886^{***}	-7.376^{***}
Preference Shock (1)	-2.012	-2.601	0.613^{**}	-10.092^{***}	-9.906^{***}
Preference Shock (2)	-1.992	-2.445	0.268	-3.318^{**}	-9.648^{***}
Government Expenditures	-2.602	-1.518	0.097	-3.530^{**}	-7.560^{***}
Taxes	-2.322	-2.569	0.109	-7.769^{***}	-7.757^{***}
M1	-1.793	-2.149	0.109	-7.082^{***}	-7.124^{***}
M3	-2.424	-2.826	0.147^{**}	-2.806^{*}	-3.939^{***}
Short-Term Interest Rate	-1.934	-1.847	0.136	-4.423^{***}	-4.496^{***}
Long-Term Interest Rate	-1.322	-1.821	0.201	-5.140^{***}	-5.154^{***}
Exports	-3.255^{*}	-2.535	0.062	-5.977^{***}	-5.847^{***}
Terms of Trade	-0.776	-1.356	0.173^{**}	-1.963	-3.373^{**}
Oil Price	-1.812	-1.394	0.190	-4.752^{***}	-4.525^{***}

Notes:

ADF: The augmented Dickey-Fuller t-statistic. The estimated model is

$$\Delta x_t = m + bt + rx_{t-1} + \sum_{i=1}^{q} a_i \Delta x_{t-i} + \epsilon_t \qquad \text{(i)}$$

and the true process is

$$\Delta x_t = \mu + \sum_{i=1}^{q} \alpha_i \Delta x_{t-i} + \epsilon_t, \qquad \text{(ii)}$$

where x_t refers to log of the variable in column 1, except in the case of interest rates. q in equation (i) was chosen to minimize the Schwarz information criterium over $p = 1, 2, ..., \bar{p}$, $\bar{p} = [12(T/100)^{1/4}]$, where $[z]$ denotes the integer part of z and T denotes the sample size, respectively (see Hayashi, 2000, p. 594 on this choice of $\bar{p}$). The test statistic is the t-statistic of the estimated r. Critical values are from MacKinnon (1991).

PP: Phillips-Peron Z_t statistic with lag truncation parameter equal to 7. The estimated model and the true process are as in (i) and (ii). The critical values are the same as those of the ADF-t statistic.

KPSS: Kwiatkowski-Phillips-Schmidt-Shin statistic of the null of stationarity. The bandwidth parameter was set to 7, critical values are taken from Kwiatkowski et al. (1992), Table 1.

The ADF-t and PP tests for the first differences of the variables in column 1 estimate the model (i) without the time trend bt and assume (ii) without the drift term μ.

*, ** , or *** denote rejection of the null at the 10%, 5%, or 1% level.

Table A.2:
Unit Root Tests 60.i-89.iv

Variable	Levels			First Differences	
	ADF	PP	KPSS	ADF	PP
Productivity Shock (1)	−1.011	−1.230	0.381***	−3.730***	−10.838***
Productivity Shock (2)	0.016	−0.427	0.381***	−5.823***	−10.258***
Preference Shock (1)	−1.911	−1.973	1.459***	−4.342***	−13.081***
Preference Shock (2)	−2.803	−2.775	1.106***	−4.950***	−12.763***
Government Expenditures	−0.682	−0.682	0.374***	−9.745***	−10.149***
Taxes	−2.742	−2.699	0.347***	−13.117***	−13.049***
M1	−2.103	−2.232	0.196**	−4.566***	−13.242***
M3	0.463	0.297	0.388***	−1.831	−4.924***
Short-Term Interest Rate	−4.335***	−2.911	0.211	−4.986***	−7.646***
Long-Term Interest Rate	−2.506	−2.261	0.326	−7.311***	−7.226***
Exports	−0.510	−1.396	0.372***	−2.404	−12.089***
Terms of Trade	−1.914	−1.869	0.202**	−3.354**	−8.047***
Oil Price	−1.874	−1.572	1.243***	−7.729***	−7.475***

Notes:

ADF: The augmented Dickey-Fuller t-statistic. The estimated model is

$$\Delta x_t = m + bt + rx_{t-1} + \sum_{i=1}^{q} a_i \Delta x_{t-i} + \epsilon_t \qquad \text{(i)}$$

and the true process is

$$\Delta x_t = \mu + \sum_{i=1}^{q} \alpha_i \Delta x_{t-i} + \epsilon_t, \qquad \text{(ii)}$$

where x_t refers to log of the variable in column 1, except in the case of interest rates. q in equation (i) was chosen to minimize the Schwarz information criterium over $p = 1, 2, ..., \bar{p}$, $\bar{p} = [12(T/100)^{1/4}]$, where $[z]$ denotes the integer part of z and T denotes the sample size, respectively (see Hayashi, 2000, p. 594 on this choice of $\bar{p}$). The test statistic is the t-statistic of the estimated r. Critical values are from MacKinnon (1991).

PP: Phillips-Peron Z_t statistic with lag truncation parameter equal to 7. The estimated model and the true process are as in (i) and (ii). The critical values are the same as those of the ADF-t statistic.

KPSS: Kwiatkowski-Phillips-Schmidt-Shin statistic of the null of stationarity. The bandwidth parameter was set to 7, critical values are taken from Kwiatkowski et al. (1992), Table 1.

The ADF-t and PP tests for the first differences of the variables in column 1 estimate the model (i) without the time trend bt and assume (ii) without the drift term μ.

*, ** , or *** denote rejection of the null at the 10%, 5%, or 1% level.

Table A.3:
Unit Root Tests 70.i-01.iv

Variable	t-Statistic	Variable	t-Statistic
Productivity Shock (1)	−2.552	Productivity Shock (M2)	−2.522
Preference Shock (1)	−2.131	Preference Shock (M2)	−1.999
Government Expenditures	−2.847	Taxes	−3.352
M1	−2.785	M3	−2.456
Short-Term Interest Rate	−3.478*	Long Term Interest Rate	−2.988
Exports	−2.151	Terms of Trade	−2.589
Oil Price	−2.650		

Notes:

a) The estimated model is

$$\tilde{x}_t = r\tilde{x}_{t-1} + \sum_{i=1}^{q} a_i \Delta \tilde{x}_{t-i} + \epsilon_t, \qquad \text{(i)}$$

where $\tilde{x}_t$ is the OLS-residual from the regression

$$x_t = c + \delta d_t + \beta t + \eta_t.$$

The dummy variable d_t is zero for quarters 70.i through 90.iv and one for the remaining quarters. Columns 2 and 3 report the t-statistic of $H_0 : r = 1$. For our sample size and choice of the breakpoint the 10%, 5%, and 1% critical values are -3.46,-3.76, and-4.32, respectively (see, Perron (1989), Table IV.B).

b) *, ** , or *** denote rejection of the null at the 10%, 5%, or 1% level.

Table A.4:
Cointegration Tests 60.i-89.iv

Variable	Model One Shock Measures							
	Productivity				Preferences			
	AIC		HQ		AIC		HQ	
	q	r_1, r_2	q	r_1, r_2	q	r_1, r_2	q	r_1, r_2
Government Expenditures	7	1,1	5	1,1	5	2,0	1	1,1
Taxes	6	1,1	1	2,2	4	0,0	1	0,0
M1	6	0,0	6	0,0	7	0,0	6	0,0
M3	6	0,0	6	0,0	8	2,2	6	2,0
Short-Term Interest Rate	6	0,0	5	2,0	5	1,1	5	1,1
Long-Term Interest Rate	6	0,0	5	0,0	4	0,0	2	1,0
Exports	6	0,0	6	0,0	6	1,0	5	0,0
Terms of Trade	6	0,0	6	0,0	6	0,0	6	0,0
Oil Price	5	1,1	2	1,1	4	0,0	2	0,0

Variable	Model Two Shock Measures							
	Productivity				Preferences			
	AIC		HQ		AIC		HQ	
	q	r_1, r_2	q	r_1, r_2	q	r_1, r_2	q	r_1, r_2
Government Expenditures	8	2,2	1	2,2	5	2,0	1	1,0
Taxes	5	1,1	1	2,2	4	0,0	4	0,0
M1	6	0,0	6	0,0	6	1,1	6	1,1
M3	6	0,0	6	0,0	6	2,0	6	2,0
Short-Term Interest Rate	5	2,0	5	2,0	5	1,1	5	1,1
Long-Term Interest Rate	6	2,0	2	0,0	4	0,0	4	0,0
Exports	5	0,0	5	0,0	6	1,0	5	0,0
Terms of Trade	6	0,0	6	0,0	6	0,0	6	0,0

Notes:
AIC and HQ refer to the Akaike and the Hannan-Quinn information criterium, respectively. q is the number of lags in the estimated model selected by AIC or HQ. r_1 (r_2) indicates the cointegrating rank according to the Johansen trace (maximum Eigenvalue) test.

Table A.5:
Cointegration Tests 76.i-89.iv

Variable	Model One Shock Measures							
	Productivity				Preferences			
	AIC		HQ		AIC		HQ	
	q	r_1, r_2	q	r_1, r_2	q	r_1, r_2	q	r_1, r_2
Government Expenditures	8	0,0	1	0,0	5	0,0	5	0,0
Taxes	8	0,0	5	0,0	4	0,0	1	0,0
M1	8	1,1	1	0,0	4	0,0	1	0,0
M3	8	1,1	5	0,0	5	0,0	5	0,0
Short-Term Interest Rate	5	0,0	5	0,0	2	0,0	2	0,0
Long-Term Interest Rate	5	0,0	1	0,0	3	0,0	1	0,0
Exports	5	0,0	5	0,0	8	0,0	2	0,0
Terms of Trade	6	0,0	6	0,0	6	0,0	5	0,0
Oil Price	5	0,0	2	0,0	4	0,0	2	0,0

Variable	Model Two Shock Measures							
	Productivity				Preferences			
	AIC		HQ		AIC		HQ	
	q	r_1, r_2	q	r_1, r_2	q	r_1, r_2	q	r_1, r_2
Government Expenditures	1	0,0	1	0,0	8	1,1	5	0,0
Taxes	5	0,0	1	0,0	4	0,0	1	0,0
M1	1	0,1	1	0,1	4	0,0	1	0,0
M3	8	1,1	8	1,1	5	0,0	5	0,0
Short-Term Interest Rate	5	0,0	5	0,0	2	0,0	2	0,0
Long-Term Interest Rate	1	0,0	1	0,0	3	2,0	1	0,0
Exports	5	0,0	1	0,0	8	0,0	2	0,0
Terms of Trade	6	0,0	6	0,0	6	0,0	5	1,1

Notes:
AIC and HQ refer to the Akaike and the Hannan-Quinn information criterium, respectively. q is the number of lags in the estimated model selected by AIC or HQ. r_1 (r_2) indicates the cointegrating rank according to the Johansen trace (maximum Eigenvalue) test.

Table A.6:
Cointegration Tests 70.i-01.iv

Variable	Model One Shock Measures							
	Productivity				Preferences			
	AIC		HQ		AIC		HQ	
	q	r_1, r_2	q	r_1, r_2	q	r_1, r_2	q	r_1, r_2
Government Expenditures	7	1,1	4	1,1	5	1,1	1	1,1
Taxes	2	1,1	2	1,1	8	1,1	1	1,1
M1	6	1,1	3	1,1	4	0,0	4	0,0
M3	6	1,1	3	2,2	4	0,0	4	0,0
Short-Term Interest Rate	2	1,1	2	1,1	5	1,1	2	1,1
Long-Term Interest Rate	2	1,1	2	1,1	4	1,0	2	1,1
Exports	5	0,0	5	0,0	5	0,0	5	0,0
Terms of Trade	6	1,1	2	0,0	6	0,0	6	0,0
Oil Price	6	0,0	2	0,0	6	0,0	5	0,0

Variable	Model Two Shock Measures							
	Productivity				Preferences			
	AIC		HQ		AIC		HQ	
	q	r_1, r_2	q	r_1, r_2	q	r_1, r_2	q	r_1, r_2
Government Expenditures	5	1,1	4	1,1	7	1,1	2	2,0
Taxes	6	1,1	2	1,1	8	2,2	1	2,0
M1	3	1,1	3	1,1	4	0,0	4	0,0
M3	3	1,1	3	1,1	4	1,1	4	1,1
Short-Term Interest Rate	2	1,1	2	1,1	2	1,1	2	1,1
Long-Term Interest Rate	2	1,1	2	1,1	4	1,1	2	1,1
Exports	5	1,1	5	1,1	5	0,1	5	0,1
Terms of Trade	7	1,1	2	0,0	6	0,0	2	0,0

Notes:
AIC and HQ refer to the Akaike and the Hanna-Quinn information criterium, respectively. q is the number of lags in the estimated model selected by AIC or HQ. r_1 (r_2) indicates the cointegrating rank according to the Johansen trace (maximum Eigenvalue) test. Since all tests were performed with a dummy variable that accounts for the break in 1991, the critical values for the Johansen tests are at best indicative of the existence of cointegration.

Table A.7:
Multivariate Granger Causality Tests 70.i-01.iv: Error Correction, r=1

Shock	q	M1→	→M1	M3→	→M4
Productivity shock (1)	3.00	0.41	0.14	0.00	0.23
Productivity shock (2)	3.00	0.12	0.19	0.00	0.42
Preference shock (1)	4.00	0.59	0.88	0.00	0.98
Preference shock (2)	4.00	0.17	0.82	0.00	0.96

Notes: q denotes the lag length of the estimated VAR in levels. In all four tests both the AIC and the HQ criterium selected the same lag length. The column labeled M1→ (M3→) displays the marginal level of significance for the null that M1 (M3) Granger causes the shock in column 1. The column labeled →M1 (→M3) displays the marginal level of significance for the null that the shock from column1 1 Granger causes M1 (M3).

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