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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 West German data from 1960.i to 1989.iv we conclude that our measures of shocks are indeed exogenous. This contrasts with similar studies for other countries that question the exogeneity of either productivity or preference shocks. For the period 70.i to 01.iv we find that M3 Granger causes all of our shock measures. We attribute this to the breaks in our time series associated with the German reunification in 1990 and the European Monetary Union in 1999.

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. Consequently, a couple of papers explore the exogeneity of this measure of supply shocks. Table I.1 presents the results of studies known to us that are close in spirit to our work.[1] Except for the paper by Paquet and Robidoux (2001) their findings do not support the hypothesis that the Solow Residual is an exogenous driving force of business cycles. Rather, it appears that monetary, fiscal, and world market variables are responsible for aggregate fluctuations.

Apologists of the real business cycle framework ascribe this lack of exogeneity to variable utilization rates of capital and labor[2], and cyclical markups[3].

Holland and Scott (1998) extend the basic framework and 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. Yet, also this measure of shocks is Granger caused by M4, the oil price, and the terms of trade.

In this paper, we examine the issue of the exogeneity of shocks for the German economy. Our motivation it twofold. First, we want to add another piece of evidence to an ongoing debate. Second, we consider the case of the German economy especially interesting: as it is

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[1] We have excluded the paper of Hall (1988), who finds that the annual growth rate of the US Solow residual is contemporaneously correlated with the growth rates of military spending and the world price of crude oil, respectively. The focus of this paper is the assumption of perfect competition, and not the exogeneity of the quarterly Solow residual as a measure of supply shocks. Furthermore, Halls methodology, t-tests in bivariate regression analysis, differs from the VAR-approach used in the studies summarized in Table I.1.

[2] See Burnside, Eichenbaum, and Rebelo (1993), Burnside and Eichenbaum (1996), Finn (1995), Paquet and Robidoux (2001)

[3] See Hornstein (1993), Rotemberg and Woodford (1992), and Hairault and Portier (1993)

Table I.1:
Synopsis of Exogeneity Studies

Author(s)	Country	Shock Measure	Granger caused by	Period
Cozier and Gupta (1993)	Canada	Solow Residual	Interest Rate (90 Day Commercial Paper Rate), Oil Price, US-GNP	1966.1-1991.4
Evans (1992)	US	Solow Residual	Narrow Money (M1), Interest Rate (90 Day Treasury Bill), Real Government Expenditures	1954.1-1983.2
Holland and Scott (1998)	UK	Solow Residual	Oil Price, Total Tax Revenues	1965.1-1994.4
		Preference Shift	Broad Money (M4), Oil Price, Terms of Trade	1965.1-1994.4
Paquet and Robidoux (2001)	Canada	Solow Residual with variable capacity utilization		1970.1-1993.4

widely acknowledged,[4] its labor market is far from being as flexible as those of the countries considered so far. Thus, if labor hoarding and market power are at the root of the problem, we expect that simple shock measures will fail to be exogenous on a grand scale.

Like in Holland and Scott (1998) our starting point is not a sophisticated dynamic general equilibrium model of the business cycle that encompasses many if not all of the monetary and real frictions that have been studied so far within this framework. Instead, we want to see whether simple models, irrespective of at what other margins they may fail, are discredited in the first place, since the shock measures they use are explained by other forces outside of the model. For this reason and since we want to see whether there are any differences to the studies mentioned in Table I.1, we first consider the usual Solow residual and the preference shift measure introduced by Holland and Scott (1998). To shed some light on the question of variable capacity utilization as well as to check for the robustness of our results with respect to small variations of the model's setup, we then consider shocks from a model that incorporates oil price shocks, capital hoarding and a declining trend in per capita working hours.

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. First, we want to exclude possible structural breaks associated with the German reunification in 1990. Second, considering the

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[4] See, e.g., Siebert (1997).

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 traditional Solow residual and the Holland and Scott (1998) preference shock as well as the more elaborate model, 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 Canada, the UK, and the US, 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. In the period where the identifying assumption of a balanced growth path is most plausible, the shocks from the model with variable capacity utilization show no sign of Granger causality. We interpret this as evidence in favor of the slightly more complex model. In addition, this result corroborates the view of Paquet and Robidoux (2001) who ascribe the lack of exogeneity of the Solow residual found by the other studies mentioned in Table I.1 to their assumption of full capacity utilization.

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:

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

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 in the studies summarized in Table I.1, 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 in Holland and Scott (1998) 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 us 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: First, working hours per member of the work force have steadily declined since the nineteen sixties.[5] Second, West Germany depends on energy imports.[6]

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 with respect to effective labor $A_t N_t$ and capital services $v_t K_t$ 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

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

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

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[5] We document this fact in Figures A.1 and A.2 in the Appendix and discuss its implications in the section on calibration. The Appendix can be downloaded from
http://www.wiwi.uni-augsburg.de/vwl/maussner/lehrstuhl/maussner/pap/dobc_appendix.pdf.

[6] The average ratio of imports of oil to GDP between 1960 an 1989 is 2.15 percent as compared to 1.18 percent (1965-1989) for the US (see 2005 Economic Report of the President), and 0.8 percent (1987-2003) for the UK (see International Trade Statistics Yearbook, Volume I Trade by Country (2002,1998,1994,1990) United Nations, New York).

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:

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

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

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

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

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:

$$\begin{aligned} G_t &= T_t, \\ G_t &= e^{g_Y t} G_0, \end{aligned}$$

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:

$$\begin{aligned}
\lambda_t &= c_t^{-\eta}(1-n_t)^{\theta_t(1-\eta)}, && \text{(II.13a)}\\
w_t &= \theta_t \frac{c_t}{1-n_t}, && \text{(II.13b)}\\
w_t &= \alpha B e^{(1-\alpha)(\psi-1)[a+\epsilon_t^A]} n_t^{\alpha-1}(v_t k_t)^{1-\alpha}, && \text{(II.13c)}\\
R_t &= (1-\alpha) B e^{\alpha(1-\psi)[a+\epsilon_t^A]} n_t^{\alpha}(v_t k_t)^{-\alpha}, && \text{(II.13d)}\\
R_t &= v_t^{\omega-1} + p_t v_t^{\gamma-1}, && \text{(II.13e)}\\
k_{t+1} &= B e^{(\alpha-1)(1-\psi)[a+\epsilon_t^A]} n_t^{\alpha}(v_t k_t)^{1-\alpha} && \text{(II.13f)}\\
&\quad + \Big(1 - (v_t^{\omega}/\omega) - p_t(v_t^{\psi}/\psi)\Big) e^{(\psi-1)[a+\epsilon_t^A]} k_t - c_t - g_t, &&\\
\lambda_t &= \beta E_t e^{\eta(\psi-1)(a+\epsilon_{t+1}^A)} \lambda_{t+1} \left(1 - (v_{t+1}^{\omega}/\omega) - p_{t+1}(v_{t+1}^{\gamma}/\gamma) + v_{t+1}R_{t+1}\right). && \text{(II.13g)}
\end{aligned}$$

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

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

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.[7] 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

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[7] Note that equation (III.3) combines equations (II.13b) and (II.13c). Thus, it is not possible to use these equations to derive different measures of the wage per efficiency unit of labor w_t. The same applies to equations (II.13d) and (II.13e), which we combine to construct v_t via equation (III.1).

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 degrees of freedom: There are 55 observations on each variable. Some of our equations have up to 18 regressor (including the error correction term) leaving only 37 degrees of freedom. 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.2.

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 $g_Y = 0.47\%$. Between 1976.i and 1989.iv hours per capita declined at an average quarterly rate of $g_N = 0.08\%$. This trend reflects three different developments:[8] 1) the declining trend in hours per employee, 2) the increasing rate of unemployment, and 3) the increasing labor force participation rate. In the framework of a representative agent model, facts 1) and 3) clearly indicate long-term shifts in the leisure-consumption preferences. Whether fact 2) reflects increasing marginal disutility of labor or is the outcome of market failures is the subject of lively debates between different macroeconomic schools of thought. However, even if one takes the position that labor market rigidities are at the core of the problem, the decreasing employment rate in the nineteen-eighties reflects a long-term, structural phenomenon and should thus not be mixed up with cyclical fluctuations. For these reasons, we think it is justified to model decreasing hours per capita as a trend and not as a cyclical phenomenon in model two. Inserting $g_Y = 0.0047$ and $g_N = 0.0008$ in (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

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[8] See Figure A.2 in the Appendix and note that hours per capita equal hours per employee times the employment ratio times the labor force participation rate.

(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 $\omega = 1.61$.

Table III.2:
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	0.0750
α	0.7235	0.7248	0.7136
δ	0.0108	0.0105	0.0117
ζ	0.0186	0.0215	0.0155

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.2 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 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 third period is of comparable size, reflecting the fact that the still positive trend of the participation rate is more than offset by declining working hours per employee and a still negative trend in the employment ratio.[9]

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: Oil Price Shocks and Utilization Rate of Capital

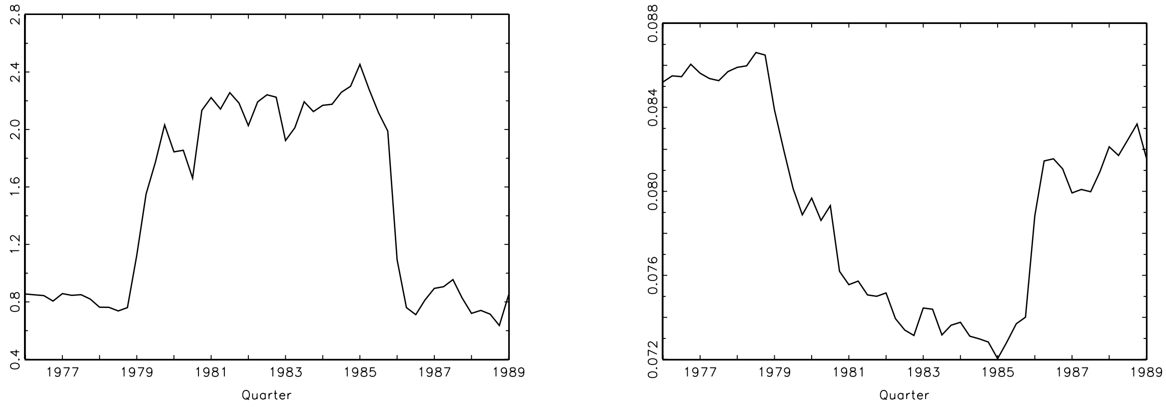

Figure III.2: Productivity and Preference Shocks: 76.i to 89.iv

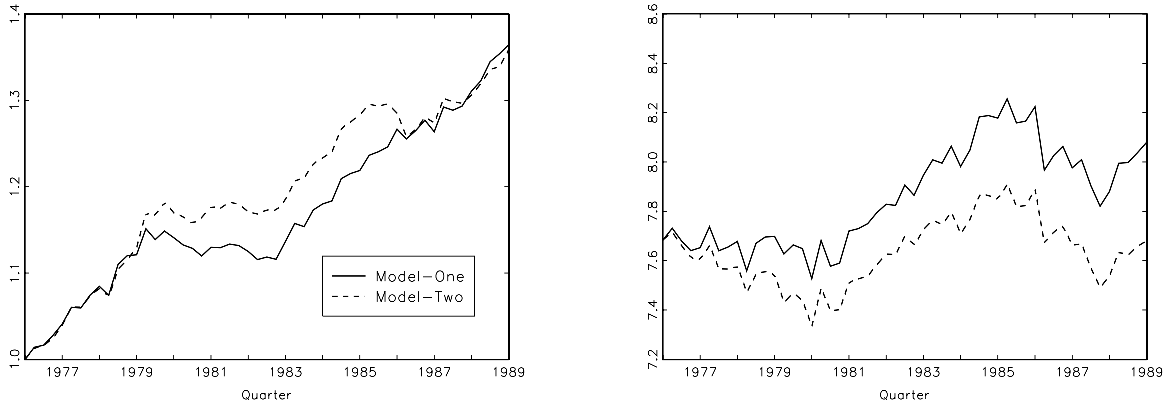

Figure III.1 displays the relative price of oil as given by the oil price index compiled at the

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[9] See Figure A.3 in the Appendix.

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 (II.6) systematically overestimates the productivity shocks during the period of high oil prices. This can be seen from the left panel of Figure III.2, where the solid line depicts the usual measure of the Solow Residual. The broken 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 solid line. The dashed 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.

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.

Being a singular event, the German reunification is a major obstacle for the identification of shocks at business cycle frequencies. Since the trends in working hours per employee, the employment rate and the participation rate are unbroken by this event,[10] the major layoffs in the eastern part of Germany appear as a sharp and sudden downward deviation from the trend in per capita working hours. Both models interpret this as a huge increase in the disutility of labor. This is certainly not a very credible story, and it may distort our results, but our simple framework provides no way around it. Given the well known low quality of public infrastructure and the obsolete private capital stock in the Neue Länder it is not surprising that both measures of the productivity shock indicate a collapse of productivity.

The size of the shocks derived from both models imply economic fluctuations of about the empirically observed magnitude. We illustrate this in Table A.1 in the Appendix that displays the results of simulations of both models using the implied time series properties of our shock measures. For instance, the standard deviation of the HP-filtered West German GDP per capita at factor costs is 1.12 vis a vis 1.51 (2.05) of the respective simulation of model one (model two). The simulations confirm well known properties of this kind of models (see, e.g., Heer and Maussner (2005), Chapter 1). Consumption is less variable in the two models than empirically, while the reverse holds for investment. The return to capital in both models is about as volatile as output and thus overstates the fluctuations of the real interest rate on three month loans, which is perhaps not a very good indicator of the return on risky investments. The autocorrelations and cross-correlations with output are quite in line between the models and the data. From the 17 moments displayed in Table A.1 ten moments

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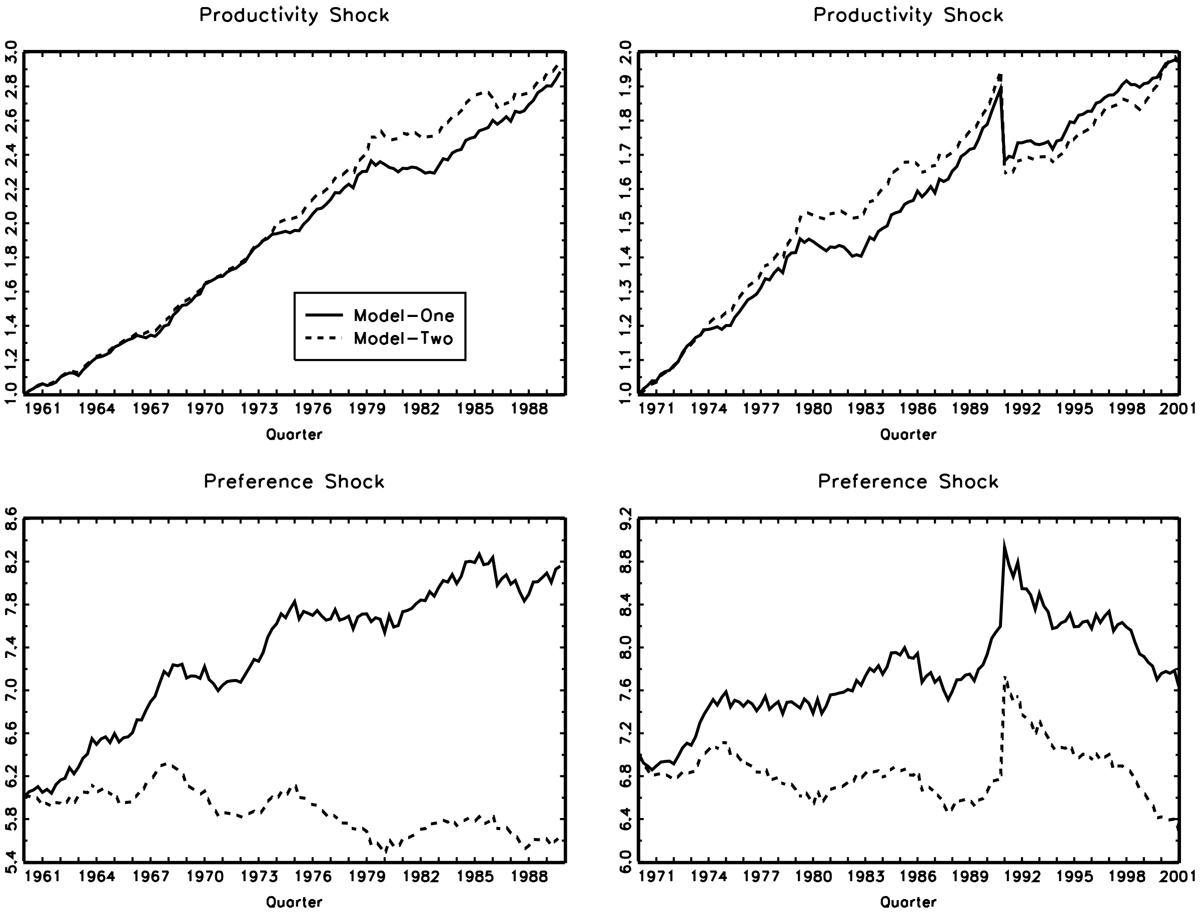
[10] See Figure A.3 in the Appendix.

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



from model two are closer or as close to the empirical figures than the respective moments from model one, indicating that this model performs slightly better.

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. This list of variables comprises those found as predictors of productivity and preference shocks in the studies cited in Table I.1 except for US GDP. Instead of this variable, we use total exports as a measure of world market demand for German products.

Like our shocks, these variables are either upward trending or display a highly persistent behavior (see Figure A.4 in the Appendix). Before we can proceed with 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.2 to A.4 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.[11] We allowed for at most 8 lags in levels. We report our results for the first two subperiods in Tables A.5 and A.6 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 exceed the one percent critical value.[12] 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.7 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.

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[11] 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).

[12] Note that if a VAR in n I(0)- and/or I(1)-variables has n cointegrating relations then the VAR is stationary in levels. In this case, however, all of its individual elements must be stationary, i.e., I(0).

Table III.3:
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.

Results of the Causality Tests Table III.3 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 conclusions 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.7. We interpret this as supportive of the model with variable capacity utilization, thus confirming the results of Paquet and Robidoux (2001) for Canada.

We have already remarked in Section 2. that 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.[13] This is one reason to extend the observation period back to the first quarter of 1960. Table III.4 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). However, in all three cases the predictive ability of the alternative shock measures is small. When we exclude them from the regression the adjusted R^2 decreases by 0.047, 0.052, and 0.052, respectively.

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.[14] It is safe 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.

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[13] We run a Monte Carlo experiment to confirm this supposition. We generated at random 100 bivariate VARs with order randomly selected between 1 and 4 and counted the number of instances where the test correctly rejected the null of no Granger causality. In the VARs with 56 observations this was on average the case in 91 percent of the simulations, whereas in the VARs with 120 observations the rejection rate was 95 percent on average.

[14] Strictly speaking the Type I error refers to repeated sampling from the same distribution. Here, we must regard each sample as a realization of a different stochastic process. Yet even under this interpretation one can expect rejection of a true null. A simple experiment confirms this: we generated two independent, stationary AR(p)-processes using random number generators to pick p, the coefficients of the two processes, the standard deviation of their innovations, and the innovations and tested for Granger causality. In 100 tests we find on average more than 5 rejections of the true null of no Granger causality.

Table III.4:
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: See Table III.3.

Do these results indicate that the West-German case is different from those of the countries considered so far? It may be too early to draw this conclusion. Our study differs from the studies gathered in Table I.1 in an important point: we employ an error correction framework whereas – except for Holland and Scott (1998) – all other investigations use growth rates or other stationary-inducing transformations of the data. However, it is well known that in the face of cointegration the estimation of a VAR in first differences provides incorrect answers. With respect to the Holland and Scott (1998) findings, this critique does not apply, and we conclude that the West-German case indeed differs from the UK.

Turning to our third subperiod this conclusion seems less robust, at least at first glance. According to Table III.5, the model-one preference shock is Granger caused by exports at

Table III.5:
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: See Table III.3.

$q = 8$, 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.6 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 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

Table III.6:
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: See Table III.3.

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.8 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 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.

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