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Procyclical Labor Productivity: Sources and Implications*

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1. Introduction

The average productivity of labor fluctuates over the business cycle and is positively correlated with output movements. This stylized fact of procyclical productivity has attracted increasing attention in recent years, as it is difficult to explain from a traditional Keynesian viewpoint where cycles are driven by aggregate demand shocks and the marginal product of labor is decreasing in output. There are three principal hypotheses that have been advanced in the literature to explain the comovement of output and productivity (see, e.g., Bernanke / Parkinson (1991)):

1. Real business cycle theory as initiated by Kydland / Prescott (1982) and Long / Plosser (1983) holds that the business cycle is the reflection of stochastic movements in the state of technology, such that output expansions are brought about by increases in total factor productivity and therefore accompanied by rising labor productivity. This technology shock hypothesis, however, suffers from shortcomings in explaining some other cyclical features of the labor market. Particularly the strong positive correlations between employment and labor productivity and the real wage rate that are predicted by this theory do not seem to be supported by empirical observations and serve as evidence against an interpretation of the business cycle as driven by large swings in technology alone.

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2. These problems do not arise when there is a role of changes in autonomous spending, e.g. government consumption, as a source of shocks. But in this case, one would expect some degree of increasing returns to scale necessary to produce the result of procyclical productivity. Given these, output fluctuations need not necessarily be ascribed to technology shocks, as any output expansion will lead to higher total factor productivity thus giving room for procyclical movements in labor productivity. Thus, increasing returns are a second possible source of procyclical productivity.
3. A third explanation, which like the second is independent of the type of shocks that give rise to output movements, is to consider cyclical variations in the rate of utilization of labor, i.e. labor hoarding behavior by firms. If utilization rises in an upswing, we get the result of *measured* labor productivity being procyclical regardless of the type of shock and even regardless of returns to scale.

In this paper, we use simulations of a dynamic general equilibrium model to study the implications of each of the aforementioned sources of procyclical productivity for aggregate labor market behavior. The basic model structure is of the real business cycle type presented in Hansen (1985), whose model is used as a reference case for the pure technology shock hypothesis. The modifications necessary to embrace the other two hypotheses are brought about by combining the work of Hornstein (1993), whose model of monopolistic competition allows the introduction of internal increasing returns to scale, with Burnside et al. (1993), who model labor hoarding as a time lag between the perception of shocks and the subsequent optimal adjustment of employment. Demand shocks derive from stochastic fluctuations of the size of the government sector that is modelled essentially as in Burnside et al. (1993), with the exception that we use proportional rather than lump-sum taxation.

Our objectives are twofold: the first is to assess the likely role of increasing returns and labor hoarding in the explanation of procyclical productivity. The second is to use simulation results as a method to determine which type of shock (technology or autonomous spending) is more likely to be an important source of fluctuations, given observed labor market regularities. In any case, our performance criterion is how much any of the mechanisms that produce procyclical productivity are able to explain other labor market features, especially the cyclical behavior of employment and wages, as well.

The empirical plausibility of labor hoarding has been documented in the recent literature.[2] There are various reasons why labor hoarding should be

[2] See, among others, Fay / Medoff (1985), Bernanke / Parkinson (1991), Basu (1996).

countercyclical and, consequently, accounts for part of procyclical productivity. First, firms are reluctant to fire people during a recession as they have invested into the human capital of their workers and face a risk of not finding equally well trained employees in the next expansion. Second, it might be expensive to adjust labor input over the business cycle. It takes time to search for workers and there might be institutional features like legal restrictions which might prevent firms from firing people on short notice. And, finally, labor contracts are signed for longer periods and before productivity of subsequent periods is observed.

The case for increasing returns to scale has been advocated by Hall in a sequence of papers (see Hall (1988), (1991)). Hall argues that the behavior of the Solow residual is inconsistent with it being interpreted as a true measure of total factor productivity. If the movement of the Solow residual reflected only true technological changes, then it should be uncorrelated with any pure demand shock that can be reasonably considered to be unrelated to technological progress. If, on the other hand, there is a correlation between demand indicators and the Solow residual, which is commonly found in empirical studies, this can be interpreted as evidence for increasing returns. In a similar vein, using vector autoregressive methods, Evans (1992) shows that aggregate demand indicators account for a substantial fraction of the variance of the Solow residual. Devereux et al. (1996) show that government spending has different effects in the neoclassical model of constant returns and a model of increasing returns to scale. In the presence of increasing returns, even a temporary change in government spending may lead to an increase in output, investment and the real wage (and therefore productivity).

The rest of the paper is organized as follows. In section 2, we present some empirical regularities of the German business cycle with emphasis on labor market features. Section 3 introduces the model, and section 4 describes the estimation and calibration of its parameters. Our results are discussed in section 5. Section 6 concludes.

2. Empirical Regularities

We present summary statistics for labor productivity, real gross national product, the average hourly wage in terms of GNP and total hours worked from 1960 to 1992 (see appendix 7.1 for details on data sources and definitions). In figure 1 we plot the cycles in output and labor productivity, using (as in the rest of this section) logarithmic deviations of seasonally adjusted quarterly data from Hodrick-Prescott trends with smoothing parameter 1600.

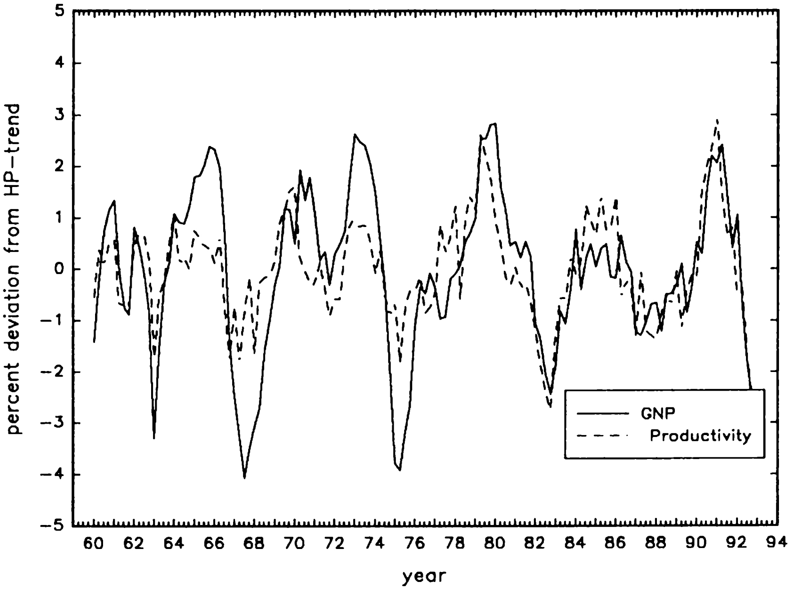

Figure 1: German productivity cycle

The strongly procyclical behaviour of labor productivity is easily seen from this picture, with a very slight lead of productivity against output. On average, a one percent deviation of output from trend is accompanied by a 0.45 percent deviation of labor productivity. Table 1 gives absolute and relative percentage standard deviations of the series and their correlations with output.

Table 1

Empirical statistics: Germany 1960 - 1992

	$\sigma_x[\%]$	$\frac{\sigma_x}{\sigma_y}$	correlations			
			y	prod	wage	hours
y	1.55	1.00	1.00			
prod	1.03	0.66	0.69	1.00		
wage	1.10	0.71	0.40	0.40	1.00	
hours	1.13	0.73	0.75	0.03	0.18	1.00

Thus, while somewhat less volatile than output, labor productivity is strongly procyclical with a correlation coefficient of 0.69. Employment, as measured by total hours worked, is more volatile than labor productivity, but still less than output. While the correlation of hours with output is markedly positive, the correlation of hours with productivity is essentially zero. This well-known 'Dunlop-Tarshis observation' (see Christiano / Eichenbaum (1992)) is one of the facts that are apparently at odds with the real business cycle view of fluctuations, where the presence of large technological shocks should lead to a strongly positive relation of employment and productivity.

The other problem with the RBC view is the behaviour of the real wage rate. Although it appears as procyclical in our data, with a modestly positive correlation of 0.40 with output, it is only weakly correlated with labor productivity and employment. Nonetheless, it is not clear wether this evidence can be taken at face value, for the aggregate wage rate is possibly contaminated by a labor force composition effect, as is claimed by Solon et al. (1994). When a disproportionately large number of less skilled workers enters the labor force in a cyclical upswing because of the improved employment opportunities, the average wage rate may rise less than it would have risen if the skill composition of the work force had remained constant. In other words, the wage rate per worker category may be more procyclical than the economywide average and positively related to employment, even if this is not apparent from aggregate data. Since we cannot correct for this possible bias, nor have evidence concerning its extent, we prefer to conclude rather cautiously that the wage rate, while being apparently procyclical, is only weakly related to movements in employment. The same conclusion holds for the correlation of employment and productivity.

Taken together, we judge the performance of the models presented below from their ability to reproduce strongly procyclical productivity and employment (the latter being more volatile than the former) on the one hand and low correlations of employment with productivity and wages on the other.

3. Modeling Procyclical Labor Productivity

The model is based on the stochastic neoclassical growth model. In this version, due to Hornstein (1993), there are four different sectors: the intermediate and final good producers, the government, and the household. The representative household maximizes his expected intertemporal utility subject to his budget constraint. The final good is produced with constant returns to scale using the intermediate goods as inputs, and can be used for both consumption and augmentation of the capital stock. The intermediate goods themselves are produced from capital and labor by monopolistically competitive suppliers who operate under increasing returns to scale and subject to a technology shock. Labor is hired before firms can observe any shock, an assumption due to Burnside et al. (1993) by which they try to capture the essence of labor hoarding. The government raises taxes on income which are spent on transfers and government consumption, the latter being also subject to stochastic shocks. We assume the government budget to balance in every period.

3.1 Households

Households are supposed to be of measure one and infinitely-lived. Households are further assumed to be identical so that their behavior can be studied with the help of a representative household. He or she maximizes the expected value of his / her intertemporal utility:

$$\max E_0 \left[\sum_{t=0}^{\infty} \beta^t U(c_t, e_t, h_t) \right] , \tag{1}$$

where β is the discount factor and expectations are conditioned on the information set as of time 0. Instantaneous utility $U(c_t, e_t, h_t)$ in period t is a function of both consumption c_t, leisure h_t, and work effort e_t. Following Hansen (1985), individuals sign a contract with the firm facing a probability n_t of getting employed and $1 - n_t$ of being unemployed. In both cases, the household receives the same wage so that the consumption and savings decisions are identical for both the employed and the unemployed. If unemployed, the household enjoys leisure at the amount of his time endowment T. If employed, the individual has to work a fixed shift length of $\bar{h}$ hours. He also faces fixed time costs of working at the amount of ζ, which might represent costs of travelling to work or forgone home production. Further, his utility is also a function of his work effort e_t if employed. Utility is assumed to be additively separable and logarithmic:

$$E_t\{U(c_t, e_t, h_t)\} = (1 - n_t)(\ln c_t + \theta \ln T) + n_t\big(\ln c_t + \theta \ln(T - \zeta - \bar{h}e_t)\big) \tag{2}$$

$$= \ln c_t + \theta n_t \ln \frac{T - \zeta - \bar{h}e_t}{T} + \theta \ln T . \tag{3}$$

The household also faces a budget constraint. He receives income from labor, capital, and profits as well as government transfers which he spends on consumption and investment:

$$c_t + i_t = (1 - \tau) w_t \bar{h} n_t e_t + (1 - \tau) r_t k_t + (1 - \tau)\pi_t + b_t , \tag{4}$$

where i_t, k_t, w_t, r_t, π_t, and b_t denote investment, the capital stock, wage, the interest rate, profits, and government transfers, respectively. Income from labor, capital, and profits is taxed at the uniform rate τ.

As capital k_t is the only asset in the economy, the household's wealth accumulates according to:

(5) $$k_{t+1} = (1-\delta)k_t + i_t \ .$$

3.2 Production

The description of the two production sectors is from Hornstein (1993). However, we also introduce labor-augmenting technological progress as the time series of German total factor productivity is non-stationary. Firms, which are owned by the households, are fixed in number and of measure one. Each firm produces one variety j of the intermediate good x. The intermediate good $x_{jt}, j \in [0,1]$, is produced by combining labor l_{jt} and capital k_{jt}:

(6) $$x_{jt} = z_t \left(k_{jt}^{\alpha} \left(\bar{h} n_{jt} e_{jt} \gamma_N^t \right)^{1-\alpha} \right)^{\gamma} - \phi_t \ ,$$

where labor is measured in efficiency units and is given by the product of time people work, $\bar{h}$, the number of people n_{jt}, and the effort e_{jt}, $l_{jt} = \bar{h} n_{jt} e_{jt}$. The variable $\phi_t \geq 0$ denotes fixed costs of production, and z_t is a common technology shock which evolves according to:

(7) $$\ln z_t = \rho \ln z_{t-1} + \epsilon_t \ ,$$

where the autocorrelation coefficient $\rho < 1$ and the random variable is normally distributed, $\epsilon_t \sim N(0, \sigma_\epsilon)$.

Thus, according to (6) there are two potential sources of scale economies: $\gamma > 1$ represents decreasing marginal cost, and any positive fixed cost $\phi > 0$ together with $\gamma = 1$ indicates decreasing average cost with constant marginal cost.

The final good y is produced with intermediate goods only. The production function is characterized by a constant returns to scale technology and a constant elasticity of substitution:

(8) $$y_t = \left[\int_0^1 x_{jt}^{\frac{1}{\mu}} dj \right]^{\mu} .$$

Firms in the final goods sector behave competitively and buy intermediate goods at price p_{jt}. In equilibrium, the price P_t of the good y_t is equal to its unit cost:

$$P_t = \left[\int_0^1 p_{jt}^{\frac{1}{1-\mu}} dj\right]^{1-\mu} \tag{9}$$

Intermediate goods producers are monopolists and face a downward sloping demand function which implies a constant markup ratio of prices over marginal cost. It is easy to show that the markup is equal to μ (see Dixit / Stiglitz (1977)). In a symmetric equilibrium, all firms in the intermediate goods sector produce the same quantity of goods, $x_{jt} = X_t$, hire the same quantity of labor, $l_{jt} = L_t$, and rent equal quantities of capital, $k_{jt} = K_t$. They also charge the same price $p_{jt} = P_t$. Normalizing prices P_t to one, equilibrium factor prices and profits are the following functions of the aggregate variables (which are denoted by capital letters):

$$w_t(K_t, N_t, E_t, z_t) = (1-\alpha)\frac{\gamma}{\mu} z_t \left(K_t^\alpha \left(\bar{h} N_t E_t \gamma_N^t\right)^{1-\alpha}\right)^\gamma / (\bar{h} N_t E_t) \ , \tag{10}$$

$$r_t(K_t, N_t, E_t, z_t) = \alpha\frac{\gamma}{\mu} z_t \left(K_t^\alpha \left(\bar{h} N_t E_t \gamma_N^t\right)^{1-\alpha}\right)^\gamma / K_t \ , \tag{11}$$

$$\Pi_t(K_t, N_t, E_t, z_t) = \left(1 - \frac{\gamma}{\mu}\right) z_t \left(K_t^\alpha \left(\bar{h} N_t E_t \gamma_N^t\right)^{1-\alpha}\right)^\gamma - \phi_t \ , \tag{12}$$

where (6), (10) and (11) have been used in the definition of profits to obtain (12). (The derivation of these equations can be found in a technical appendix that is available on request.) Notice that (10) – (12) above are identical to equations (15 a - c) in Hornstein (1993).

The profit maximization problem of the intermediate goods producers does not have a well-defined solution if the price-marginal cost markup, μ, is smaller than the scale elasticity γ; the case $\mu < \gamma$ is therefore ruled out. Absent any fixed costs, profits would be zero if $\mu = \gamma$ and positive when $\mu > \gamma$. In the simulations below, we calibrate the fixed cost, ϕ, in order to ensure zero profits on average, i.e. in the model's steady state, as does Hornstein (1993). The implied exclusion of firm entry or exit is surely not meant to represent a realistic feature of a monopolistically competitive economy. Rather, our focus is on increasing returns to scale, for which to be compatible with a competitive solution monopolistic competition is chosen here as a framework. Note that adapting the magnitude of fixed costs to ensure zero steady state profits enables us to study the two sources of increasing returns separately: if we set $\mu = \gamma$, profits are zero *in every period* and fixed costs are therefore zero, so that increasing returns are entirely due to decreasing marginal costs. If, on the other hand, $\mu > \gamma$ and $\phi > 0$, we have decreasing average costs even if γ were one and marginal cost therefore constant, and profits would be procyclical though zero in the steady state.

3.3 Implications of the Exogenous Technological Progress

In a steady state, output y will grow at a constant rate γ_x. In this section, the necessary conditions for the existence of a steady state will be analysed.

Define the growth rate of output to be:

$$\gamma_x \equiv \frac{y_{t+1}}{y_t} \tag{13}$$

From (8), obviously $\frac{x_{t+1}}{x_t} = \gamma_x$, too.

In a steady state, in accordance with empirical observations, the interest rate and capital productivity are constant. Therefore, capital grows at the same rate as output, $\frac{K_{t+1}}{K_t} = \gamma_x$. In a balanced growth equilibrium, profits will be zero as motivated above. For this reason, we assume that the fixed cost of production ϕ grow at the rate γ_x:

$$\phi_t = \bar{\phi}\gamma_x^t \; . \tag{14}$$

From (6), the steady state growth rate γ_x and the labor progress index γ_N are related as follows:

$$\gamma_N = \gamma_x^{\frac{1-\alpha\gamma}{(1-\alpha)\gamma}} \; . \tag{15}$$

Consequently, wages will grow at the rate γ_x, too, while the interest rate is constant. Define stationary output as $\tilde{y}_t \equiv y_t/\gamma_x^t$, and similarly for the other variables $\tilde{x}_t$, $\tilde{w}_t$, $\tilde{k}_t$, $\tilde{c}_t$, $\tilde{i}_t$, and $\tilde{\pi}_t$. Henceforth, the model will be expressed in terms of the stationary values.

3.4 The Government

Government expenditures consist of government consumption G_t and government transfers B_t to households. Government consumption will grow at the same rate as output, $G_t = \tilde{G}_t\gamma_x^t$, and is subject to an exogenous stochastic component:

$$\tilde{G}_t = g_t \bar{G}, \tag{16}$$

$$\ln g_t = \rho_g \ln g_{t-1} + \eta_t, \quad |\rho_g| < 1 \ , \tag{17}$$

where η_t is distributed normally, $\eta_t \sim N(0, \sigma_g)$. We assume $\bar{G}$ to be a constant percentage of steady state output, $\bar{G} = g_0 \bar{y}$, so that the government share is constant in the steady state under certainty.

Government expenditures are financed by a tax on income and the government budget is assumed to balance in every period:[3]

$$\tau \bar{h} N_t E_t \tilde{w}_t + \tau r_t \tilde{K}_t + \tau \tilde{\Pi} = \tilde{G}_t + \tilde{B}_t \ . \tag{18}$$

3.5 The Stationary Rational Expectations Equilibrium

The household maximizes his utility as given in (1). As in Burnside et al. (1993), we assume that households and firms must choose n_t before z_t and g_t are observed. Let Ω_t^* denote the information set at the beginning of time t, $\Omega_t^* = \{z_{t-1}, g_{t-1}, \tilde{K}_t, \tilde{k}_t\}$, and Ω_t the one after oberserving z_t and g_t, $\Omega_t = \{z_t, g_t, \tilde{K}_t, \tilde{k}_t\}$. The effort e_t, consumption $\tilde{c}_t$, and investment $\tilde{i}_t$ are chosen subject to the information set Ω_t. The wage rate $\tilde{w}_t$ and the interest rate r_t will also be contingent on Ω_t.

Accordingly, the first decision problem of the household is to choose its labor supply n_t relative to the state vector $(z_{t-1}, g_{t-1}, \tilde{K}_t, \tilde{k}_t)$, while the second decision problem is to choose e_t, $\tilde{i}_t$ and $\tilde{c}_t$ relative to $(z_t, g_t, \tilde{K}_t, \tilde{k}_t)$. In the formulation of the household's dynamic optimization problem it is important to distinguish between the aggregate variables $(\tilde{K}_t, N_t, E_t, \tilde{I}_t)$ and their individual counterparts $(\tilde{k}_t, n_t, e_t, \tilde{i}_t)$. The decision rules are the following value functions:

$$V_0(\tilde{K}_t, \tilde{k}_t, z_{t-1}, g_{t-1}) = \max_{n_t} E\left[V_1(\tilde{K}_t, \tilde{k}_t, z_t, g_t)|\Omega_t^*\right] \ , \tag{19}$$

and

$$V_1(t) = \max_{\{\tilde{c}_t, \tilde{i}_t, e_t\}} \left(\ln \tilde{c}_t + n_t \theta \ln\left(\frac{T - \zeta - \bar{h} e_t}{T}\right) + \beta E\left[V_1(t+1)\right] \middle| \Omega_t \right) \ , \tag{20}$$

[3] An increase in government spending for given output decreases lump-sum transfer payments. For a constant tax rate τ, this is equivalent to an increase in debt financing as demonstrated by Barro (1974).

with $V_1(t) = V_1(\tilde{K}_t, \tilde{k}_t, z_t, g_t)$ and subject to (4), (5), (7), (10), (11), (12), and (18) and

$$(21) \qquad \tilde{K}_{t+1}\gamma_x = (1-\delta)\tilde{K}_t + \tilde{I}_t \ .$$

A *stationary rational expectations equilibrium* consists of a collection of individual and aggregate decision rules $\{\tilde{i}_t, \tilde{I}_t, e_t, E_t, n_t, N_t, \tilde{c}_t, \tilde{C}_t\}$ such that

1. $\{\tilde{i}_t, e_t, n_t, \tilde{c}_t\}$ solves the household optimization problem (19) and (20).
2. Aggregate variables equal individual variables:

$$(22) \qquad \tilde{K}_t = \tilde{k}_t \ ,$$

$$(23) \qquad \tilde{I}_t(\tilde{K}_t, z_t, g_t) = \tilde{i}_t(\tilde{K}_t, \tilde{k}_t, z_t, g_t) \ ,$$

$$(24) \qquad E_t(\tilde{K}_t, z_t, g_t) = e_t(\tilde{K}_t, \tilde{k}_t, z_t, g_t) \ ,$$

$$(25) \qquad \tilde{C}_t(\tilde{K}_t, z_t, g_t) = \tilde{c}_t(\tilde{K}_t, \tilde{k}_t, z_t, g_t) \ ,$$

$$(26) \qquad N_t(\tilde{K}_t, z_{t-1}, g_{t-1}) = n_t(\tilde{K}_t, \tilde{k}_t, z_{t-1}, g_{t-1}) \ .$$

3. Aggregate profits $\tilde{\Pi}_t$ accrue to the household at equal amounts $\tilde{\pi}_t = \tilde{\Pi}_t$ and are zero in the long run.
4. Factor markets clear.
5. The government budget balances at any time.

A solution to this problem provides decision rules for investment, consumption, labor, and effort supply by the individual household depending on the information sets Ω_t^* and Ω_t, respectively. The conditions characterizing the steady state can be found in the appendix in section 7.2; the numerical computation of the decision rules is described in the technical appendix which is available on request.

4. Calibration

This section describes the specific parameter values we have chosen for the simulation of the model.

Utility

For utility function parameters, we chose the usual discount rate of $\beta = 0.99$. Total time endowment is normalized to one, so the fixed shift length of work is set to $\bar{h} = 0.3$. The fixed utility cost parameter of going to work, ζ, is taken from Burnside et al. (1993) to be 0.05.[4] The parameter θ is calibrated with the help of the steady state conditions of the respective model.

Production

The deterministic growth rate of output, γ_x, is calculated from the slope of an exponential trend through gross national product as $\gamma_x = 1.007$. From the observed average employment rate in our data sample we infer the steady state employment rate n to be equal to 0.964. Capital depreciates at a quarterly rate that is on average 0.0104 according to the national product accounts.

The determination of plausible values for the price-marginal cost markup μ and the scale elasticity γ is empirically difficult. We have experimented with the estimation method of Hall (1991). While this posed some problems, our best guess turned out to be around $\mu = \gamma = 1.5$. Insofar as there is reason to believe in some upward bias in these estimates, we prefer to see this as an upper limit on the range of plausible values, and hence compare the results with those obtained from setting either of these parameters to one in the simulations reported below.[5]

The autoregressive parameter of technology shocks, ρ, is set at 0.95 to achieve comparability with previous studies. The standard error of the technology shock, σ, is commonly estimated from the Solow residual in the RBC literature. As this measure of total factor productivity is seriously biased both through the existence of increasing returns and cyclical factor utilization, we do not follow this convention. We prefer to calibrate the parameter σ for each of our model specifications in such a way that the respective model reproduces the empirically observed volatility of output. Thus, the σ-values used below imply no hypotheses about the actual variations in technology, but rather indicate the amount of technological fluctuations that one would have to take for granted if the respective model structure represented the true model of the economy.[6]

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[4] Like Burnside et al. (1993), we found the results to be insensitive with regard to the choice of the parameter ζ.

[5] Hornstein (1993) uses a value of 1.5, too. Domowitz et al. (1988) find markups in the range of 1.4 to around 2.0 for US industries. Further, it may be noted that by the choice of the scale elasticity γ, our steady state is saddle point stable, and there will be a unique rational expectations equilibrium. Only for values of γ in excess of 1.64, the steady state is a sink.

[6] According to a referee's suggestion, we have reported the standard deviation of each model's *implied* (HP-filtered) Solow residual (named $\sigma_{SR)}$ in table 4 below. If we chose the technology variance in each case to match the empirical variance of the implied Solow residual, instead of output volatility, no qualitative conclusion would have to be altered. Details are shown in the technical appendix available on request.

Government

The steady state share of government expenditure in gross output is set at 0.19, which is the average of the ratio of government consumption to GNP. We measure shocks to government demand as the deviation from an exponential trend line that is seen to represent a constant deterministic growth rate. The first order autoregressive parameter of this series is estimated to be $\rho_g = 0.98$ from an OLS autoregression with standard error $\sigma_g = 0.0105$, which serves as our measure of the volatility of government shocks. Finally, we take the tax rate on income as $\tau = 0.3$.[7]

The following table gives an overview of the parameter values chosen.

Table 2

Parameter choice

β	0.99
$\bar{h}$	0.3
ξ	0.05
γ_x	1.007
δ	0.0104
μ	1.5; 1
γ	1.5; 1
$\bar{g}$	0.19
ρ_g	0.98
σ_g	0.0105
τ	0.3
ρ	0.95

5. Numerical results

The essential features of the model are declining marginal cost, markups, and labor hoarding. Out of the eight possible combinations of these, we simulated the six model varieties that make sense economically (because we cannot have price equal to marginal cost when marginal cost declines). Table 3 summarizes the model characteristics.

[7] The marginal income tax rate of the average income in Germany is about 35%, while the average income tax rate is approximately 25%. We also tested our model for these two values, but results did not differ significantly. Note also that our benchmark case $\tau = 0.3$ is roughly in line with estimates of Baxter / King (1993) for the US economy.

Table 3

Overview of model characteristics

	Model number:						
	Hansen	I	II	III	IV	V	VI
Parameters	$\mu = 1$ $\gamma = 1$	$\mu = 1.5$ $\gamma = 1.5$	$\mu = 1.5$ $\gamma = 1.5$	$\mu = 1.5$ $\gamma = 1$	$\mu = 1.5$ $\gamma = 1$	$\mu = 1$ $\gamma = 1$	$\mu = 1$ $\gamma = 1$
Fixed costs	no	no	no	yes	yes	no	no
Labor hoarding	no	yes	no	yes	no	yes	no
Stochastic government	no	yes	yes	yes	yes	yes	yes

Table 4 displays summary statistics on the results of simulation experiments. As mentioned in the previous section, the standard deviation of the technology innovation, σ^*, was in each case calibrated in order to have the model match the empirically observed volatility of output. The statistic σ^*/σ_y in the first row of table 4 thus indicates the strength of the internal shock propagation mechanism of the respective model, with a low coefficient meaning a larger amplitude of the impulse response of output.

Table 4

Numerical results of simulations

			Model number						
Statistic	Germany	U.S.	Hansen	I	II	III	IV	V	VI
σ^*/σ_y	(σ_y=1.55)	(σ_y=1.72)	0.475	0.345	0.319	0.419	0.433	0.516	0.463
σ_{SR}	1.11		0.92	1.02	0.94	1.41	1.32	1.12	0.89
σ_{prod}/σ_y	0.66	0.52	0.411	0.572	0.417	0.880	0.817	0.639	0.400
σ_n/σ_y	0.73	0.92	0.632	0.639	0.646	0.244	0.268	0.651	0.669
σ_w/σ_y	0.71	0.32	0.411	0.439	0.417	0.519	0.499	0.455	0.400
corr (prod, y)	0.69	0.41	0.94	0.80	0.91	0.97	0.98	0.77	0.89
corr (prod, n)	0.03	– 0.20	0.83	0.36	0.76	0.39	0.60	0.20	0.73
corr (w,n)	0.18	– 0.13	0.83	0.62	0.76	0.32	0.48	0.44	0.73

See table 3 for a description of model characteristics.

Statistics for the U.S. that are included for comparison purposes are taken from Cooley/Prescott (1995), Christiano/Eichenbaum (1992) and Andolfatto (1996); employment figures refer to hours worked according to household survey.

σ_{SR} is the percentage standard deviation of the HP-filtered implied Solow residual, $SR = \ln y_t - 0.64 \ln n_t - 0.36 \ln k_t$.

The first column of the table includes for comparison purposes the results for the standard RBC model with indivisible labor by Hansen (1985), here augmented by a non-stochastic government sector and calibrated for the German economy. Taking this as a benchmark case, we have that the volatility of the technology shock amounts to 47.5% of output volatility. As can be seen from the remaining columns of table 4, this value is decreased somewhat by the introduction of 1) decreasing marginal cost (models I and II), 2) decreasing average cost with constant marginal cost (models III and IV), and 3) shocks to government demand (models V and VI in comparison to the Hansen (1985) benchmark). Labor hoarding tends to smooth output movements slightly. The most notable reduction in the required technology variance appears under increasing returns to scale through decreasing marginal cost (models I and II).

In the sequel, we discuss the effects of each of these mechanisms in turn. While all models (apart from the baseline Hansen (1985) model) include stochastic government demand shocks, the effect of these shocks is tiny in comparison to the technology shock, which can be seen in table 4 by comparing the required technology shock in the Hansen (1985) benchmark (47.5 % of the standard deviation of output) and in model VI (46.3 % of the standard deviation of output), which are identical apart from the existence of a government demand shock. Thus, the quantitative effects of government shocks of the postulated magnitude (namely, with a standard innovation of the error term, σ_g, of 0.0105) are very small. We discuss the qualitative effects of demand shocks in greater detail below, where we intend to show that the failure of these shocks to form a basis on which to explain procyclical productivity does not rely on a particular estimation of their magnitude.

5.1 Decreasing Marginal Cost

The introduction of decreasing marginal cost in the model ($\gamma > 1$, see models I and II in table 4) has significant impacts on the propagation of shocks. The technology variance that is necessary to reproduce empirical output volatility is only about two thirds of the one needed in the benchmark Hansen (1985) case, namely 34.5 % of output volatility with labor hoarding and 31.9 % without. This is in line with the results of Hornstein (1993). Without labor hoarding, however, the most notable change is in the scale of fluctuations, not in their qualitative features (compare models II and VI). Productivity is procyclical, certainly, but its volatility is not larger than in the benchmark case and empirically still too low, while its correlation with output is still exaggerated by this model. The other labor market features that we consider, the employment-productivity and employment-wage correlations, are much too high, as in the standard RBC model. The principal effect of increasing returns taken alone is basically to act as a scaling factor for fluctuations.

5.2 Fixed Costs

In models III and IV, marginal cost is constant, $\gamma = 1$, but there are large markups, $\mu = 1.5$. The resulting pure profits are zero in the steady state due to the calibration of the fixed costs, but are clearly procyclical outside the steady state. Labor's share in income is inversely proportional to the markup (see Hornstein (1993)); hence a given shock will raise wages and labor input less than with $\mu = 1$. This is one element of the explanation why employment is less than half as variable in model III (or IV) than in model V (or VI).[8] The other is that procyclical profits accrue as income to private households, so that any expansionary shock implies a wealth effect that ceteris paribus reduces the increase in labor supply resulting for intertemporal substitution reasons.

At the same time, a given employment expansion results in a larger output response than in a perfectly competitive model, since due to the fixed costs the output elasticity of labor is greater, so that the required technology shock variance is still smaller than in a model with $\mu = 1$ and no fixed costs, as model V or VI. This explains, too, why productivity is much more volatile (88 % of output's standard deviation in III and 82 % in IV) than in any other model parametrization that we consider, and more volatile than empirically (66 % of output volatility).[9] This reversion in the order of magnitude of employment and productivity fluctuations is clearly at odds with empirical findings. There is, however, a remarkable reduction in the employment-wage correlation that is clearly due to the fact that an increase in the marginal product of labor following a technology shock is not fully paid out to workers when the intermediate goods market is noncompetitive.

5.3 Labor Boarding

In models I, III, and V, labor hoarding is introduced as caused by a lag between the hiring and production decision, following Burnside et al. (1993).[10]

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8 Thanks are due to an anonymous referee for pointing this out.

9 For the same reason the volatility of the implied Solow residual increases sharply in models III and IV.

10 Model V is most similar to Burnside et al. (1993). In fact, the only difference is the form of government financing: we assume income rather than lump-sum taxation.

In response to a positive productivity shock, wages and income increase. The wealth effect reduces labor supply while the increasing wage causes workers to supply more effective labor. The net effect on effective employment is positive. As labor contracting takes place just over one period, effort only changes for one period and returns to its steady state value in the period immediately following the temporary technology shock.[11] As a consequence of the procyclical effort, labor productivity fluctuates more. The change in effective labor as measured by the product of effort and hours worked, $e_t n_t \bar{h}$, is smaller in the case of labor hoarding than in the case of no labor hoarding. This follows immediately from the household utility function where employment n_t enters linearly, while the effort e_t only enters logarithmically. As a consequence, the response of output to a technology shock is smaller in the case of labor hoarding, which is also reflected in the higher σ^*/σ_y-ratio. Due to procyclical effort, labor hoarding further decreases the procyclicity of labor productivity as measured by the correlation of actual hours worked and productivity.[12] In any of the models in table 4, thus, labor hoarding brings the simulated statistics somewhat closer to the empirical ones. This is true irrespective of the magnitude of markups and returns to scale.

5.4 The Role of Government Demand

Government spending shocks are a source of disturbances that may have different effects on fluctuations than the technology shocks usually studied in the RBC literature. Their impact may furthermore differ according to which propagation mechanims are included in the respective model. Particularly, we are interested in the question whether fiscal effects are a candidate solution for the empirical finding of procyclical productivity with a low wage-employment correlation. As stated above, the contribution of government demand shocks to the overall volatility of fluctuations is very small for the parametrization we found empirically plausible. This can be confirmed by a look at figures 2 and 3 in appendix 7.3, where we have plotted

[11] Fairise/Langot (1991) introduce adjustment costs into a model with labor hoarding. Employment and effort respond more smoothly to productivity shocks. However, the variability of employment and labor productivity is reduced.

[12] Effort movements over the business cycle have received increasing attention in recent models of real business cycles. Danthine/Donaldson (1990) develop a model of efficiency wages emphasizing the gift exchange paradigm. Uhlig/Xu (1996) use the theory of efficiency wages in order to study the behavior of effort. In their models, effort is countercyclical. Employers work harder and shirk less if the threat of unemployment increases. As a result, employment movements are larger while real wages display smaller cyclical movements. However, the model's implication are difficult to reconcile with the phenomenon of procyclical labor productivity.

the impulse response functions of a one percent shock to government spending and technology, respectively, relative to the steady state values of the respective variables. The output effects of government demand shocks turn out to be 8 to 10 times lower than those of technology shocks.

The question we follow here is whether the qualitative aspects of the models' response to demand shocks make them likely to be a plausible explanation for procyclical productivity in this type of model at least in principle. Looking at table 4, we see that e.g. in model VI (compared to the pure technology shock Hansen (1985) benchmark) although the relative volatilities of productivity and employment do not change much, the correlations of productivity with output and employment are reduced somewhat, thus leading to a slight improvement in model performance.[13]

The reason is, clearly, that the strong link between productivity and output that is introduced through technology shocks is weakened when part of total output volatility is allowed to derive from spending shocks. As tax rates are constant in the model, any increase in actual spending decreases the lump-sum transfer for any given level of output. This negative wealth effect results in an increase in labor supply and an increase in the interest rate, the latter reflecting the intertemporal substitution of consumption by the household.[14] While the interest rate effect on investment is negative, the effect of the increase in employment is positive as the marginal product of capital rises. The net effect is positive for all of our calibrations.

While this is true for any of the cases we consider, the net effect on productivity and wages differs across model specifications (see figure 2 in appendix 7.3) .*i)* With constant returns to scale and price equal to marginal cost (models V and VI), the increased labor supply has to be accomodated by reduced labor productivity and wage.[15] *ii)* The case of a markup greater than one together with constant marginal cost (models III and IV) leads to virtually the same output response of government shocks, but the employment response is reduced substantially (for reasons noted above). For our parameter constellation, the net effect of increased capital and labor input on productivity almost cancels out, leaving only a very slight increase in productivity and a decrease in the wage rate. *iii)* In the decreasing marginal cost economy (models I and II), finally, the positive effect of an increase in

13 These effects are a bit more pronounced when we assume lump-sum taxation (not reported).

14 The effect, of course, depends on the nature of the government shock and, in particular, on the value of ρ_g. Note that with an estimated parameter $\rho_g = 0.98$ we are discussing something very close to a 'permanent' government demand shock; see Aiyagari et al. (1992).

15 Here as in all the other cases, labor hoarding makes a qualitative difference only for the initial periods following a shock, insofar as productivity rises unambiguously before effort is normalized and employment adjusts.

government spending on output and employment is most pronounced. A 1% increase in government spending increases employment by 0.35% in the first period following the shock (which translates into almost the same output percentage increase in our calibration). The strong response of investment eventually results even in a net increase in labor productivity and wages.

The qualitative similarity of technology and government demand shocks under decreasing marginal cost might lead to the conjecture that government and technology shocks are perfect substitutes for the explanation of the business cycle in this case. Any cyclical pattern that is commonly seen as explicable through technology shocks in the RBC literature could apparently be explained as well only through variations in autonomous spending, given a sufficiently high degree of returns to scale. To show why this conjecture is wrong, consider table 5, where we have recomputed statistics for our models I and II, but now only with government shocks as a driving force, i.e. setting σ_g to the value necessary to reproduce empirical output volatility and setting σ, the variance of technology shocks, to zero.[16]

Table 5

Only government demand shocks with increasing returns

Model:	σ_g^*	σ_{prod}/σ_y	σ_n/σ_y	correlations		
				(prod, y)	(prod, n)	(w,n)
I	0.045	0.472	1.117	– 0.03	– 0.45	– 0.38
II	0.041	0.089	1.045	– 0.43	– 0.50	– 0.50

Recalling that model I includes labor hoarding whereas model II does not, it is clear from these results that even though labor hoarding is still sufficient to produce a volatility of measured productivity that is roughly in the range that is empirically observed, the output-productivity correlation is essentially zero even in this case. Further, the employment-productivity correlation as well as the employment-wage correlation are turned negative. Thus, the combination of labor hoarding and government shocks *alone* is not sufficient to produce procyclical productivity, the reason being (as can be seen from the impulse response graphics in figure 2 of appendix 7.3) the gradual rather than immediate response of productivity in the aftermath of a government shock.

16 For any of the models with constant marginal cost, the sole reliance on fiscal spending shocks leads, as expected, to an almost perfectly negative correlation between wages and employment, so that we need not report those irrelevant results here.

It follows that for a model structure like the one considered here technology shocks are indispensable to account for the stylized fact of procyclical productivity. The role of increasing returns is rather doubtful. Shocks to government demand are helpful to explain the rather low productivity-employment and wage-employment correlations that are observed empirically. To produce the combined outcome of strongly procyclical productivity and low wage-employment correlation, the model has to be equipped with labor hoarding. Given this, there will exist a mixture of government demand and technology shocks that produces reasonable features of labor market behaviour in a constant returns to scale economy. Among the model versions we considered, model V (labor hoarding with constant returns) performs relatively best (though far from impressively).

5.5 The Role of Government Financing

Income taxation rather than lump-sum taxation reduces the response of employment to a shock. A positive technology shock results in higher wages, a positive government spending shock reduces wealth and hence leisure (normal good). As, however, wages are taxed at rate τ, the household faces smaller incentive to increase its labor supply than in the case of no taxes. This can be seen directly from the steady state conditions (29) and (31) in appendix 7.2. Consequently, output and employment fluctuate less, while the correlation of productivity and output increases. The effect is strongest in the case I and II of increasing returns. In model I, the standard deviation of the technology shock σ^* necessary to produce observed output volatility falls by one third compared to the case with $\tau = 0.3$. However, income taxation rather than lump-sum taxation does not change the qualitative results profoundly.[17]

6. Conclusions

Much of the appeal of real business cycle theorizing stems from its ability to explain procyclical productivity. However, the strongly positive wage-employment correlation that is predicted by RBC models because of their reliance on technology shocks is typically not found in empirical data. This paper has investigated the extent to which the assumption of technology

[17] In the model, an increase in government spending is financed by a reduction in transfers or, equivalently, by debt. If, instead, the government adjusts the income tax rate each period in order to finance its spendings, the qualitative results will change significantly as demonstrated by Baxter / King (1993).

shocks can be substituted through other mechanisms, namely labor hoarding and increasing returns to scale.

Our main results can be summarized as follows: 1) Technology shocks are indispensable as a source of fluctuations in labor productivity. Shocks to government demand alone do not generate procyclical productivity even with increasing returns to scale. 2) Labor hoarding seems to be important in explaining the cyclical behaviour of productivity and employment. 3) Increasing returns mainly result in a strong reduction of the size of the technology shock necessary to reproduce the observed volatility of output.

7. Appendix

7.1 Data

Here we document the data sources which are the basis of the empirical statements in the main text.

Sources

Data are mainly from the quarterly national account statistics of the German Institute for Economic Research (DIW), Berlin. The series are for West Germany and are seasonally adjusted, with the exception of depreciation, which was adjusted by the authors using seasonal dummies. The net real capital stock was computed by the perpetual inventory method using a starting value for 1960 published by the German Statistical Office (Statistisches Bundesamt). Data on employed, unemployed and self-employed persons were taken from the German Statistical Office, too. As these series are recorded quarterly only since 1968, we interpolated linearly between yearly values for the period 1960 to 1967.

Definitions

The DIW publishes a series of hourly productivity, which were used as our indicator of average labor productivity. Total hours worked were derived as the denominator of this series. The nominal wage rate is total compensation divided by total hours, and was converted to the real wage rate by dividing through the price index of gross national product. The series for labor's share in income was computed by adding measured labor income to the number of self-employed persons times the average labor income of employed persons, and dividing through nominal gross national product.

7.2 Steady State under Certainty

In the steady state, consumption, output and investment will all grow at the constant rate γ_x. For this reason, it turns out to be convenient to use the following transformation of the variables in order to calculate the steady state conditions:

$$\tilde{c}_t \equiv \frac{c_t}{\gamma_x^t}, \tilde{i}_t \equiv \frac{i_t}{\gamma_x^t}, \tilde{x}_t \equiv \frac{x_t}{\gamma_x^t}, \tilde{k}_t \equiv \frac{k_t}{\gamma_x^t}, \tilde{w}_t \equiv \frac{w_t}{\gamma_x^t}, \tilde{b}_t \equiv \frac{b_t}{\gamma_x^t}, \tilde{\pi}_t \equiv \frac{\pi_t}{\gamma_x^t}. \tag{27}$$

The first-order conditions and envelope condition of the household's optimization problem are:

$$\frac{1}{\tilde{c}_t} = \lambda_t \ , \tag{28}$$

$$\lambda_t(1-\tau)\tilde{w}_t = \frac{\theta}{T - \zeta - \bar{h}e_t} \ , \tag{29}$$

$$\lambda_t \frac{\gamma_x}{\beta} = E\left[\lambda_{t+1}(1 + (1-\tau)r_{t+1} - \delta) \mid \Omega_t\right] \ , \tag{30}$$

$$-\theta E\left[\ln \frac{T - \zeta - \bar{h}e_t}{T} \mid \Omega_t^*\right] = E\left[\lambda_t(1-\tau)\tilde{w}_t\bar{h}e_t \mid \Omega_t^*\right] \ , \tag{31}$$

where

$$\lambda_t = E\left[\frac{\beta}{\gamma_x}\frac{\partial V(t+1)}{\partial \tilde{k}_{t+1}} \mid \Omega_t\right] \ . \tag{32}$$

$\Omega_t^* = \{z_{t-1}, g_{t-1}, \tilde{K}_t, \tilde{k}_t\}$ is the information set before observing the technology and government shock of period t, while $\Omega_t = \{z_t, g_t, \tilde{K}_t, \tilde{k}_t\}$ is the information set of the households after oberserving the two shocks.

The following transversality condition is imposed:

$$\lim_{t\to\infty} E_0\left[\beta^t \lambda_t \tilde{k}_{t+1}\right] = 0 \ . \tag{33}$$

In the steady state under certainty, $z_t \equiv 1$, $g_t \equiv 1$, and the variables $\tilde{c}_t$, $\tilde{x}_t$, $\tilde{w}_t$, $\tilde{k}_t$, $\tilde{i}_t$, e_t, and n_t will be constant. Profits $\tilde{\pi}_t$ will be zero. The steady state conditions are given by the following nonlinear equation system in the three endogenous variables $\bar{e}$, $\bar{n}$, and $\bar{k}$:

$$\frac{\theta}{T - \zeta - \bar{e}\bar{h}} = (1-\tau)\frac{\bar{w}}{\bar{c}} \ , \tag{34}$$

$$\frac{\gamma_x}{\beta} - 1 + \delta = (1-\tau)\bar{r} \ , \tag{35}$$

$$\ln T - \ln(T - \zeta - \bar{h}\bar{e}) = \frac{\bar{e}\bar{h}}{T - \zeta - \bar{h}\bar{e}} \ , \tag{36}$$

where

$$\bar{c} = \bar{y} - \bar{G} - (\gamma_x - 1 + \delta)\bar{k} \ , \tag{37}$$

$$\bar{G} = g_0 \bar{y} \ , \tag{38}$$

$$\bar{y} = \frac{\gamma}{\mu}\left[\bar{k}^{\alpha}(\bar{n}\bar{e}\bar{h})^{1-\alpha}\right]^{\gamma} \ , \tag{39}$$

$$\bar{w} = (1-\alpha)\frac{\gamma}{\mu}\left[\bar{k}^{\alpha}(\bar{n}\bar{e}\bar{h})^{1-\alpha}\right]^{\gamma}/\left(\bar{n}\bar{e}\bar{h}\right) \ , \tag{40}$$

$$\bar{r} = \alpha\frac{\gamma}{\mu}\left[\bar{k}^{\alpha}(\bar{n}\bar{e}\bar{h})^{1-\alpha}\right]^{\gamma}/\bar{k} \ . \tag{41}$$

7.3 Impulse Response Functions

The figures on the following pages give the impulse response of output, labor productivity and employment for a shock of size 0.01 to government demand and technology, respectively, for each of the models presented in the text. The responses are expressed relative to the steady state values of the respective variable.

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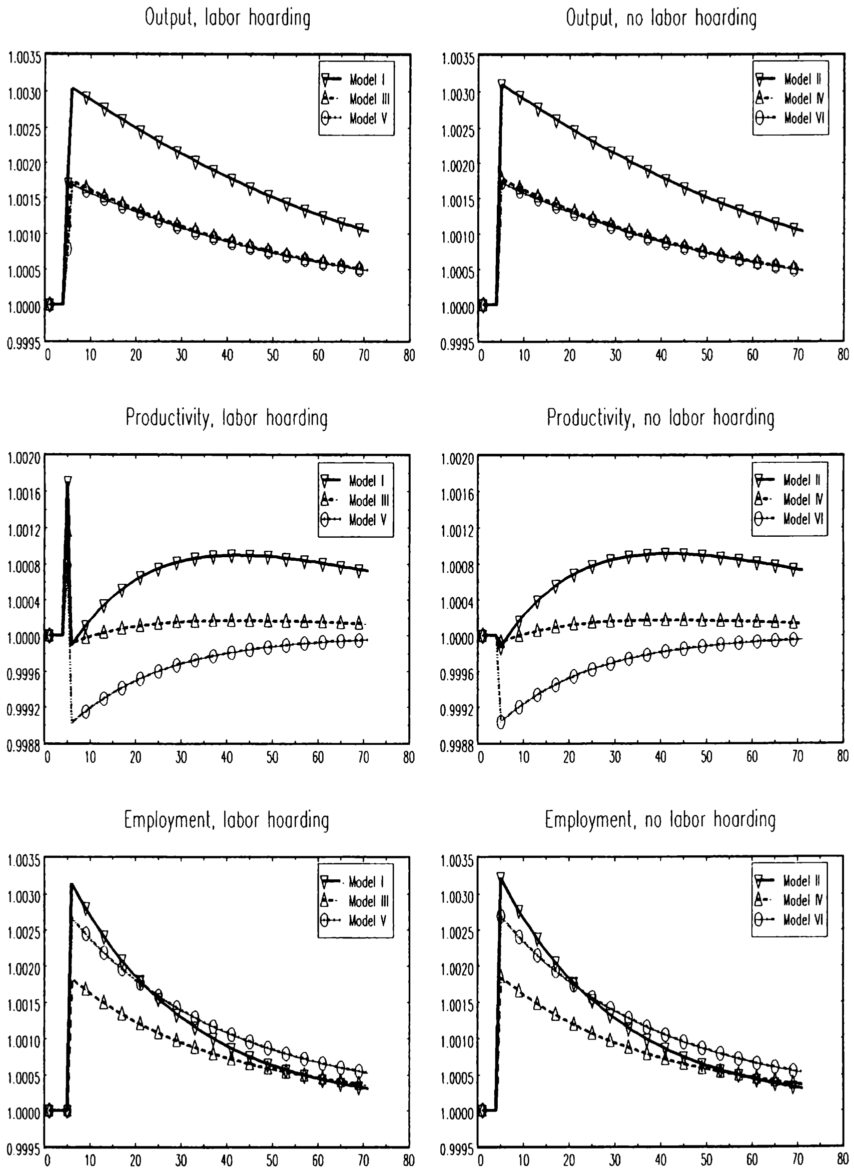

Figure 2: Response to a government demand shock (time axis measured in quarters)

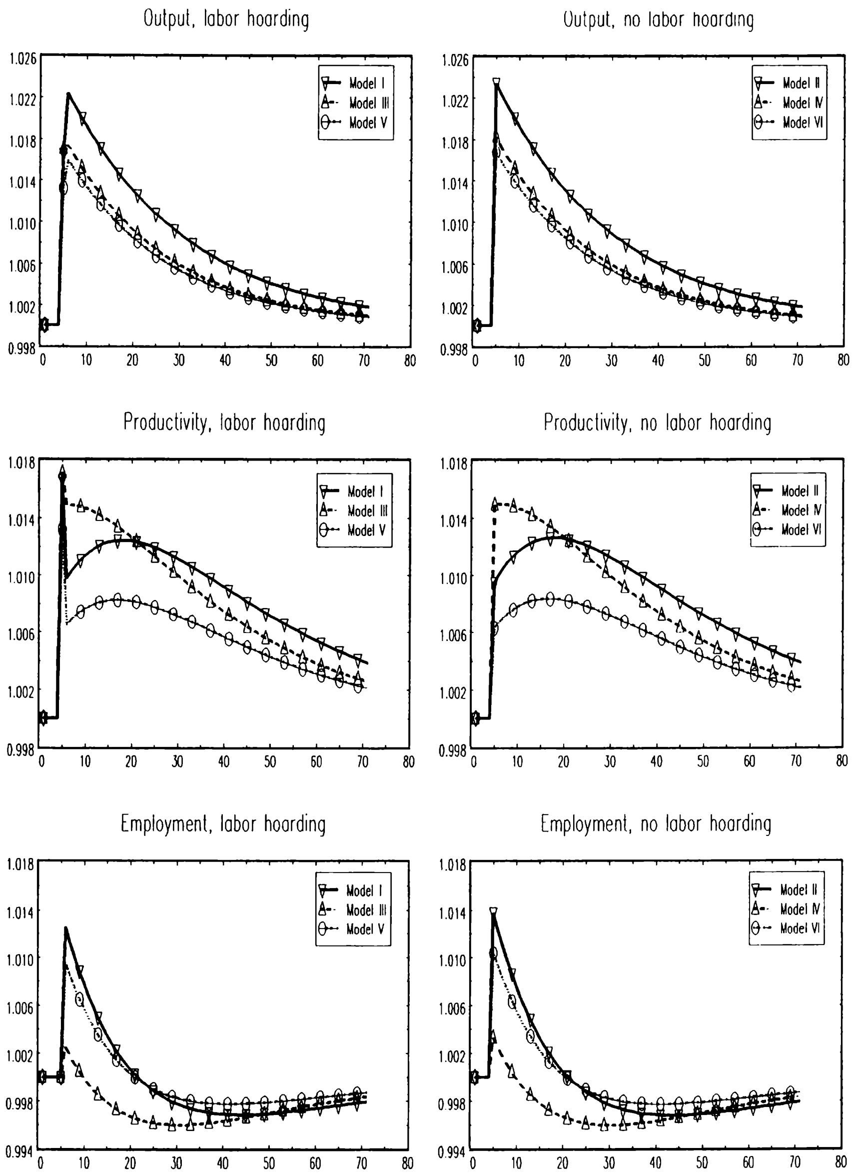

Figure 3: Response to a technology shock (time axis measured in quarters)

Zusammenfassung

Die durchschnittliche Produktivität der Arbeit verhält sich in entwickelten Volkswirtschaften typischerweise prozyklisch. In der Literatur sind drei verschiedene Erklärungsansätze für dieses stilisierte Faktum vorgebracht worden: 1) technologische Schocks, 2) Arbeitskräftehortung und 3) zunehmende Skalenerträge in der Produktion. Unter Verwendung der Arbeiten von Hornstein (1993) und Burnside et al. (1993) konstruieren wir ein Real Business Cycle-Modell, das alle drei genannten Möglichkeiten zuläßt und dessen Parameter so gewählt werden, daß sie die wichtigsten quantitativen Eigenschaften empirischer Konjunkturzyklen in Deutschland widerspiegeln. Bei der Simulation werden ein Technologieschock und ein Staatsnachfrageschock vorgegeben. Die wesentlichen Resultate sind: 1) Technologische Schocks scheinen in diesem Modellrahmen unabdingbar zu sein, da Nachfrageschocks alleine nicht in der Lage sind, prozyklische Arbeitsproduktivität zu erzeugen, nicht einmal unter Zulassung von steigenden Skalenerträgen. 2) Arbeitskräftehortung scheint eine bedeutsame Rolle für die Erklärung der zyklischen Schwankungen von Produktivität und Beschäftigung zu spielen. 3) Zunehmende Skalenerträge führen im wesentlichen nur zu einer Reduktion der zur Erzeugung von Schwankungen erforderlichen Schockvarianz.

Abstract

Labor productivity in modern industrialized countries is procyclical. Three different explanations for this empirical observation have been proposed in the literature: 1) technological shocks, 2) labor hoarding, and 3) increasing returns to scale in production. Combining elements by Hornstein (1993) and Burnside et al. (1993), we integrate these features in a real business cycle model that is calibrated to match empirical observations on German data. We allow for two types of shocks, a technology shock and a shock to government consumption. Our main results can be summarized as follows: 1) Technology shocks are indispensable as a source of fluctuations in labor productivity. Shocks to government demand alone do not generate procyclical productivity even with increasing returns to scale. 2) Labor hoarding appears to be important in explaining the cyclical behaviour of productivity and employment. 3) Increasing returns mainly result in a strong reduction of the size of the technology shock necessary to reproduce the observed volatility of output.

JEL-Klassifikation: E 32, E 24, E 62, J 22