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Post reunification economic fluctuations in Germany: A real business cycle interpretation

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**Post Reunification Economic Fluctuations in
Germany: A Real Business Cycle
Interpretation**

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Post Reunification Economic Fluctuations in Germany: A Real Business Cycle Interpretation*

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Abstract

We consider the cyclical properties of the German economy prior and after reunification in 1990 from the perspective of a real business cycle model. The model provides the framework for the selection and consistent measurement of the variables whose time series properties characterize the cycle. Simulations of the calibrated model reveal the model's potential to interpret the data. Major findings are that: i) the volatility of most aggregate time series has not changed significantly between the two time periods, ii) despite many conceptual differences between the European and the U.S. System of Accounts, the calibrated parameter values for the German economy are within the range of values usually employed in the real business cycle literature, iii) the model is closer to the data for the time period prior to reunification.

JEL classification: C82, E01, E32

Keywords: Macroeconomic Data, Measurement and Data on National Income and Product Accounts, Economic Fluctuations, Real Business Cycles

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1 Introduction and Motivation

Since the seminal papers of Kydland and Prescott (1982), Long and Plosser (1983), and Prescott (1986), among others, it has become standard praxis to consider business cycles (BC's) within the framework of dynamic stochastic general equilibrium (DSGE) models. This class of models shares the basic ingredients of the first-generation models, namely intertemporal optimization and rational expectations, but also allows for many frictions as, e.g., real or nominal price stickiness, limited participation in financial markets, or obstacles in the allocation of labor.¹ Recent models, e.g. the model of Smets and Wouters (2003), a replacement of the Area Wide Model (AWM) of the European Central Bank (ECB), can replicate NK effects in the short-run (determined by aggregate demand) and neoclassical effects in the long-run (determined by aggregate supply). Medium scale DSGE models are useful for economic policy evaluation. Their increased complexity vis-a-vis the first-generation models, however, makes them less suited for studying elementary driving forces of the BC. However, as has been widely documented in the empirical literature, the stylized facts of the BC have remained relatively stable over time and region.² This suggests that elementary economic mechanism shape the cycle more than many institutional details. For this reason we will employ a first-generation real business cycle (RBC) model to organize ideas about economic fluctuations prior and after the territorial status of the Federal Republic of Germany of October 03, 1990, where the entire considered time period covers the first quarter of 1970 until the last quarter of 2012.

The motivation is twofold. First, we want to ask whether the nature of the German BC has changed. As a reference we take the West German economy, West Berlin included, over the period 1970:I-1991:IV. The split of the period 1970:I-2012:IV into two subsamples is not only marked by the German reunification but also by a major change in the German National Income and Product Accounts (GNIPA). As a data base we employ data provided by the German Federal Statistical Office (GFSO), which rest on the European System of Accounts (ESA). Only recently the GFSO finished the revision of data prior to 1991 on the occasion of the great revision in 2005, so that a set of comparable data is available.³ The second motivation is to explore to what

¹Such models are known as New Keynesian (NK) models, which were widely established by Mankiw (1989), Mankiw and Romer (1991), as well as Cho and Cooley (1995), among others.

²See for instance Cooley and Prescott (1995), pp. 29-33, for a description of the U.S. BC facts.

³See Braakmann et al. (2005) and also the Subject-matter series 18, S.27. For the comparability of time series between the period 1970-1991 and 1991-2004, see also R  th et al. (2006).

extend the new GNIPA data allows to consistently calibrate an RBC model that can be used to interpret the data. This endeavor is similar to the work of Cooley and Prescott (1995) and Gomme and Rupert (2007) for the U.S. economy. There are, however, conceptual differences between the NIPA System in the U.S. and in Europe that necessitate deviations from the work of these authors. As a result of this work, we have gathered a data base suitable for calibrating DSGE models to German data.⁴

The main findings are i) that with respect to the volatility of major macroeconomic aggregates the BC has not changed significantly,⁵ that ii) despite several differences in data and methodology we find parameter values within the range of those estimated for the U.S. economy, and iii) that - taking into account the uncertainty in the estimated second moments - the model is closer to the data for the period 1970:I-1991:IV.

The next section describes the theoretical model. This model provides the framework for the selection and definition of variables employed to calibrate the model and to characterize the BC in section 3. Section 4 provides the results and section 5 concludes.

2 Theoretical Framework

As a framework for (1) the selection of data that characterize the BC, (2) the consistent calibration, and (3) the interpretation of the empirical findings we employ the RBC model of Heer and Maußner (2009), chapter 1.5. This model abstracts from population growth, but is otherwise similar to the model of Cooley and Prescott (1995). Thus, we exclude home production and investment-specific shocks as in Gomme and Rupert (2007), because these authors already argue on p. 489 that "removing home production from the model has little effect on the model's predicted business cycle moments" and because their results indicate that adding such an investment-specific shock only leads to more volatility of almost every considered macroeconomic series and brings the model more at odds with the real data.

The economy is populated by a representative firm and a representative household. Time t is discrete.

The Firm. A representative firm produces output, Y_t , according to the constant returns to scale production function

$$Y_t = Z_t F(A_t N_t, K_t), \tag{2.1}$$

⁴An Excel sheet with the regarding pre-adjusted time series is available upon request.

⁵As it is also reported by Buch et al. (2004).

where the firm employs labor and capital services, N_t and K_t . Total factor productivity (TFP), Z_t , is governed by the covariance-stationary, stochastic process

$$\ln Z_t = \rho \ln Z_{t-1} + \sigma \epsilon_t, \quad \epsilon_t \sim \mathcal{N}(0, 1), \quad \rho \in (0, 1). \quad (2.2)$$

Labor augmenting technical progress, A_t , grows deterministically at the gross rate $a \geq 1$:

$$A_{t+1} = aA_t. \quad (2.3)$$

The firm takes the real wage, W_t , and the rental rate of capital, r_t , as given and maximizes its current-period profits

$$\Pi_t = Y_t - W_t N_t - r_t K_t. \quad (2.4)$$

This provides two conditions that will hold in the equilibrium of the labor market and the market for capital services:⁶

$$\frac{W_t}{A_t} = Z_t F_N(A_t N_t, K_t), \quad (2.5a)$$

$$r_t = Z_t F_K(A_t N_t, K_t). \quad (2.5b)$$

The Household. A representative household supplies labor and capital services to the firm, consumes, and accumulates capital. Capital depreciates at a rate $\delta \in (0, 1]$, so that

$$K_{t+1} = (1 - \delta)K_t + I_t \quad (2.6)$$

is the law of motion of the capital stock, where I_t denotes gross fixed investments. The household's period-to-period budget constraint, thus, reads:

$$W_t N_t + r_t K_t \geq C_t + I_t. \quad (2.7)$$

The household values consumption, C_t , and leisure, $1 - N_t$, according to the current-period utility function $u(C_t, 1 - N_t)$. This function is strictly increasing in consumption and leisure and strictly concave. The household discounts future utility $t + s$ at the rate β^s , $\beta \in (0, 1)$, and maximizes his expected life-time utility

$$U_t = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s u(C_{t+s}, 1 - N_{t+s}),$$

subject to the budget constraint (2.7) and a given stock of capital, $K_t > 0$. Expectations, $\mathbb{E}_t$, are conditional on information available at time t .⁷

⁶We denote the partial derivatives of a function F with respect to its argument $x \in \{N, K\}$ by a subscript.

⁷For this, see also Maufner (2013b), pp. 59-60.

In addition to the budget constraint, which holds at equality in equilibrium, and the law of motion of the capital stock two further equations characterize the household's optimal plan:⁸

$$W_t = \frac{u_{1-N}(C_t, 1 - N_t)}{u_C(C_t, 1 - N_t)}, \quad (2.8a)$$

$$u_C(C_t, 1 - N_t) = \beta \mathbb{E}_t u_C(C_{t+1}, 1 - N_{t+1})(1 - \delta_t + r_{t+1}). \quad (2.8b)$$

The first condition determines the household's labor supply. It equates the real wage to the marginal rate of substitution between leisure and consumption. The second condition is the Euler equation for capital accumulation. It equates the disutility from savings with the discounted expected future reward.

Equilibrium. In equilibrium factor markets clear so that the household's budget constraint reduces to

$$Y_t = C_t + I_t. \quad (2.9)$$

Equations (2.1), (2.5), (2.6), (2.8a), (2.8b), (2.9), and (2.2) fully describe the dynamics of the model. Due to (2.3) the economy will grow over time and exhibit fluctuations around its balanced-growth path which are driven by the covariance-stationary shocks to TFP, Z_t .

Parameterization. Except for a few special cases DSGE models as the one presented in the previous paragraphs do not have an analytical solution. The rules describing the household's choice of consumption and leisure must be approximated with the help of numerical methods. Among the most popular methods are perturbation methods that yield a polynomial approximation at the stationary solution of the non-stochastic version of the model. To apply these methods the researcher must specify the functional form of the production function F and the utility function u and transform the model to a stationary one.

On the firms side we follow Heer and Maußner (2009) as well as Cooley and Prescott (1995) and employ a Cobb-Douglas production function

$$F(A_t N_t, K_t) = (A_t N_t)^{1-\alpha} K_t^\alpha, \quad \alpha \in (0, 1) \quad (2.10)$$

⁸We denote the partial derivatives of a function u with respect to its argument $x \in \{C, 1 - N\}$ by a subscript.

with capital share parameter α .

Since the model depicts a growing economy, the household's preferences must be chosen so that conditions (2.8) are consistent with a constant supply of hours and a constant growth rate of consumption. The function

$$u(C_t, 1 - N_t) = \frac{1}{1 - \eta} [C_t^{1-\eta}(1 - N_t)^{\theta(1-\eta)} - 1], \quad \eta > \frac{\theta}{1 + \theta} \quad (2.11)$$

has this property and is strictly concave in consumption and leisure, as mentioned before. The parameter η equals the coefficient of relative risk aversion and its inverse is the elasticity of intertemporal substitution. θ is the share parameter for leisure in the composite commodity.

Given these parameterizations it is easy to see that scaling all growing variables by the level of labor augmenting technical progress, A_t , transforms the model to a stationary one. We will use lower case letters to refer to these scaled variables.

Stationary Solution. The stationary solution of the non-stochastic model can be computed in the following steps: (1) set $Z_t \equiv 1 \forall t$. This is the long-run value of Z_t implied by the process (2.2) if $\sigma = 0$. (2) scale growing variables by A_t . (3) assume that the dynamics has ceased so that $x_{t+1} = x_t = x$ for all variables of the model.

Applying this procedure to equations (2.1), (2.5), (2.6), (2.8a), (2.8b), and (2.9) yields the following equations:

$$\frac{y}{k} = \frac{a^\eta - \beta(1 - \delta)}{\alpha\beta}, \quad (2.12a)$$

$$y = N^{1-\alpha} k^\alpha, \quad (2.12b)$$

$$y = c + i, \quad (2.12c)$$

$$\theta \frac{c}{y} = (1 - \alpha) \frac{1 - N}{N}. \quad (2.12d)$$

Equation (2.12a) follows from equation (2.5b) and the Euler condition (2.8b). Equation (2.12b) is the production function for $Z \equiv 1$, written in stationary variables $y = Y/A$ and $k = K/A$. Equation (2.12c) is the resource constraint (2.9), also written in stationary variables $c = C/A$ and $i = I/A$. And equation (2.12d) follows from (2.5a) and the labor supply condition (2.8a). We will return to these equations when we discuss the results from the calibration procedure for the simulation of the model in subsection 4.1.

3 Empirical Framework

3.1 Trend and Cycle

The model laid out in the previous section predicts the short- and long-run behavior of the observable variables

- output Y ,
- consumption C ,
- investments I ,
- hours N , and
- real wage W .

We will use this set of variables to characterize the BC.

Seasonal Adjustment. Quarterly economic data contains a seasonal and calendar component, which are not explained by the model. Thus, the researcher must use seasonal- and calendar-adjusted time series. The GFSO employs an indirect approach to remove the seasonal and calendar component from a time series. It computes seasonal- and calendar-adjusted aggregates as the sum of seasonal- and calendar-adjusted subaggregates.⁹ For the adjustment either the Berlin Method (currently Version 4.1) or the Census X-12-ARIMA method is employed.¹⁰ Since more time series adjusted with the latter method are available, we will use the Census X-12-ARIMA method throughout.

Trend Removal. To achieve stationarity of the time series, its trend must be removed. To isolate the cyclical component in a time series, the popular filter by Hodrick and Prescott (1997), the HP-Filter, is used.¹¹ In detail, detrending occurs by filtering

⁹For example, see the Subject-matter series 18, S.23 and especially for the time period 1970 till 1991 the Subject-matter series 18, S.28

¹⁰See <https://www.destatis.de/DE/Methoden/Zeitreihen/Zeitreihenanalyse.html> for a detailed description and the regarding differences of these two methods. See also <http://www.census.gov/srd/www/x13as/> for the X-13ARIMA-SEATS Seasonal Adjustment Program, which is the successor of the Census X-12-ARIMA.

¹¹For different methods concerning detrending in general and their different implications on the considered time series, see Canova (1998).

the log of the time series. For quarterly data it is customary to choose the smoothing parameter $\lambda = 1600$, because of the normally assumed BC fluctuation frequencies from about three to five years.¹²

Second Moments. A standard tool to evaluate DSGE models is to compare the second moments of simulated time series with those of the respective macroeconomic aggregates. Therefore the set of the following second moments of the variables introduced above will be used to uncover the properties of the RBC model and to characterize the cycle:

- standard deviation,
- standard deviation relative to standard deviation of output,
- cross-correlation with output,
- cross-correlation with hours, and
- first-order autocorrelation.

3.2 Price Adjustment

The variables output, consumption, investments, and the real wage are measured in units of the final good. The data collected in the GNIPA is based on nominal aggregates and need to be deflated by some measure of the price level. Before the revision in 2005, real variables were defined with respect to the price system of a particular base year. The advantage of this concept is that real magnitudes, such as consumption, investments, and net exports add up to GDP. The disadvantage is that changes in relative prices, which induce changes in the composition of subaggregates, cannot be taken into account. Thus, constant price aggregates are intertemporally not really comparable. Since 2005, the real time series of the GFSO are reported as chain indices, which include a kind of non-linearity and therefore face the problematic characteristic of non-additivity.¹³ The deflators of the main aggregates, such as GDP, consump-

¹²See for instance Cooley and Prescott (1995), pp. 27-29.

¹³See Mayer (2001), Braakmann et al. (2005), and also the Subject-matter series 18, S.24. For a more sophisticated contemplation of the properties of chain indices and the possibilities for the computation of chained and unchained real aggregates, see the Appendix, which is available upon request. See also von der Lippe (2000) for critical comments on chain indices in general. And for a detailed dispute with U.S. chain aggregated NIPA data, see Whelan (2002).

tion expenditures, and gross investments, are meanwhile also constructed from chained indices, so that the real aggregates are intertemporally comparable, but the subaggregates do no longer add up without a residual. This residual is greater, the greater the relative prices have changed, and this effect is known as "substitution bias".¹⁴

To tackle the problem of structural inconsistency of the computable chained real aggregates in a certain frame, we follow Gomme and Rupert (2007) in line with Greenwood et al. (1997). The former authors mention on p. 484 that "a common price deflator should be used when converting nominal NIPA data into real terms and that a natural choice is the price deflator for nondurable goods and nonhousing services", and designate their weighted average deflator out of the two just mentioned price deflators simply as the consumption deflator. Greenwood et al. (1997), pp. 347-348, mention that such a choice is natural because they want "to avoid the issue of the accounting for quality improvement in consumer durables". In our context such a weighted price index (PI) corresponds with the consumer PI (CPI) for Germany, since this is also the average price development of all goods and services purchased by households for consumption by purpose.¹⁵ But since the above described model framework and the data pre-adjustments for a consistent measurement also include the net exports, the GDP-deflator is the corresponding or rather adequate PI. Following Reich (2003) and Balk and Reich (2008) as well, who argue that a GDP-deflator should be used because this implies a measure of inflation and growth. Therefore all four nominal main aggregates will be deflated by one common PI, which is the GDP-deflator, to guarantee a data and model consistent fashion. Since the chain indices for the subsample 1991:I till 2012:IV are reported with the reference year 2005, where the average of this year is set to 100, there first has to be made a rebasing to the year 1991, to achieve that the two subsamples are comparable.¹⁶

¹⁴Between 1991 and 2004 the GDP residual (difference between the directly determined chained real GDP and the sum of the chained real GDP components) differ at most 0.4% in relation to real GDP, as Nierhaus (2005b) mentions. Residuals arise naturally also in spatial units, such as between real GDP at the federal level and the accumulated GDP of the 16 states in Germany. For this, see Nierhaus (2001), Nierhaus (2004a), Nierhaus (2004b), and again Nierhaus (2005b). Gomme and Rupert (2007) also mention that already in the late 1990s the U.S. BEA pointed out that it is not appropriate to add real magnitudes. For this, see also Braakmann et al. (2005), and R  th et al. (2006). There are also difficulties with values reached by balances, as net exports or inventory investments, if they are zero. See, among others, Nierhaus (2005b), Nierhaus (2007), and T  dter (2005).

¹⁵This price deflator is also available over the entire period, however, the PI, which refers to the former Federal Territory of Germany, is reported as the PI for living of all households.

¹⁶Note, that for the second subperiod hedonic PI's are used, which also include a quality aspect.

3.3 Consistent Measurement

Definitions and Constructions. Given that the data availability in Germany is different to the data availability in the U.S.,¹⁷ the following considerations focus on the German case.¹⁸

Starting from the use approach perspective of the new GNIPA data and keeping in mind that the theoretical framework does not distinguish between government and private consumption (C_{gov} and C_{pr}) as well as investments, the private consumption expenditures in the data can be decomposed into long-lived durables, short-lived durables, non-durables, and services.¹⁹ Only long-lived durables are included as I_{prdur} in the composite gross fixed investments, I , since these can be regarded as a kind of investment goods. For total consumption, C , therefore follows:

$$C = C_{gov} + C_{pr} - I_{prdur},$$

which is consistent in the model context.

Cooley and Prescott (1995), p. 38, argue that when "there is no foreign sector in this economy, net exports are viewed as representing additions to or claims on the domestic capital stock, depending on whether they are positive or negative". We follow this argumentation and add the whole net exports as I_{NE} to the total gross investments, I , which also include government and private gross fixed capital formation or rather gross fixed investments (GI_{gov} and GI_{pr}) as well as changes in inventories (CI_{gov} and CI_{pr}). Thus I can be written as:

$$I = GI_{gov} + GI_{pr} + CI_{gov} + CI_{pr} + I_{prdur} + I_{NE} = GI + I_{prdur} + I_{NE}.$$

Therefore output reads:²⁰

$$Y = C + I,$$

where Y stands consistently for GDP in data, which is valued at market prices.²¹ But

¹⁷For example, GDP is reported in the GNIPA within the production and the use approach, but not within the distribution approach, because of missing data. This is in contrast to the reported GDP in the U.S.

¹⁸See the Appendix for a more detailed description of the following steps, wherein all computations are made with the nominal magnitudes. Note, that for convenience the time subscripts are repressed.

¹⁹It should also be mentioned that the time series of consumption expenditures used here also include home-based services. See Braakmann et al. (2005) and Burghardt (2006).

²⁰This is also the resource constraint for the whole economy (2.9).

²¹In this paper the conceptually appropriate measure of output is GDP rather than GNP, also because of deflation problems. See Brümmerhoff and Lützel (2002), pp. 59 f. and 62 f. For this, see also Gomme and Rupert (2007).

since the model framework assumes Y at factor prices, Y has to be adjusted in the sense of a subtraction of net taxes to get a valued GDP at factor prices. Then Y is consistent to the model.

The labor measure, N , is calculated as the average quarterly fraction of total hours worked and the real wage, W , is calculated as the nominal wage divided by the GDP-deflator.²²

For the construction of a quarterly composite capital stock time series, the annual net fixed capital plus the annual net stock of durable goods of the households can be combined with the calculated quarterly total gross investments with the "Perpetual Inventory Method" (PIM) to obtain such an adequate capital stock measurement.²³ For this purpose an interpolation method is conceivable: Let K_{tq} denote the capital stock in quarter q of year t . The GFSO provides capital stock data for each year and data on gross investments, I_{tq} , for each year and quarter. Therefore, we can interpolate between two years, t and $t + 1$, in the following way:

$$K_{t+1} = I_{t4} + (1 - \delta_{tq})I_{t3} + (1 - \delta_{tq})^2 I_{t2} + (1 - \delta_{tq})^3 I_{t1} + (1 - \delta_{tq})^4 K_t.$$

The variable δ_{tq} is the implicit rate of depreciation of the quarterly capital stock in year t . Given K_{t+1} , K_t , I_{tq} , $q = 1, 2, 3, 4$, we can solve for the unique $\delta_{tq} \in (0, 1)$. The time variant or rather variable quarterly depreciation rate, δ_{tq} , is the solution of this method to achieve that the capital stock at the end of period t is the same as the capital stock at the beginning of period $t + 1$.²⁴ The average of this depreciation rate, δ , is used in subsection 4.1 for the calibration in each subsample.

Cooley and Prescott (1995) calibrate the Solow residual without fixed capital, arguing that the quarterly variations in the aggregate capital stock are approximately zero and so the omission of the capital stock has only little effect on the Solow residual at BC frequencies, which are typically between 6 and 32 quarters. They argue further in line with Prescott (1986) that any interpolation method for constructing a quarterly capital stock will be arbitrary and will bring some noise into the measures, because the

²²With this PI the main focus is on firms perspective, unlike the PI for final domestic use or the CPI, where the main focus is on households perspective. See the Appendix for a description of the different calculation opportunities of PI's in the GNIPA.

²³See also Heer and Maußner (2009), Gomme and Rupert (2007), and the Appendix for the construction of the capital stock. The latter also includes a briefly contemplation of the PIM used by the GFSO for the construction of the capital stock.

²⁴An advantage of such a depreciation rate is that it is delimited equal as the composite capital stock and the total gross fixed investments.

capital stock series are only reported annually in the U.S. and in Germany. However it poses some difficulties as well to avoid the whole time series, also in consideration of the fact that the statistical offices, e.g. the GFSO, as well use extra- and interpolation methods for the construction of some time series.²⁵ For this argumentation, see also Gomme and Rupert (2007), who compute the Solow residual with and without a capital stock (aggregated as well as separated for market structures and equipment and software).²⁶ They find similar results of these three different methods, so that the parameter estimates of the Solow residual are not too sensitive between these different calculations. We further compute the Solow residual without a capital stock and with a composite capital stock, where net fixed assets and the net stock of household durables are included, so that the Solow residuals can be computed as $z_{t1} = \frac{y_t}{eh_t^{1-\alpha}}$ and $z_{t2} = \frac{y_t}{eh_t^{1-\alpha} k_{t1}^\alpha}$, where eh_t denotes efficient working hours. The deviations from balanced growth are therefore $\hat{z}_{t1} = \frac{z_{t1} - \bar{z}_{t1}}{\bar{z}_{t1}}$ and $\hat{z}_{t2} = \frac{z_{t2} - \bar{z}_{t2}}{\bar{z}_{t2}}$, respectively.

Used Variables. The following list crudely enumerates the used variables for the pre and post reunification in the periods 1970:I-1991:IV and 1991:I-2012:IV:

1. Output measure Y_t : GDP at factor prices
2. Consumption measure C_t : Private and public consumption of non-durables
3. Investment measure I_t :
 - i Private and public gross fixed investments
 - ii Private and public gross fixed investments plus changes in inventories plus private consumption of consumer durables plus net exports²⁷
4. Capital measure K_t : Private and public net fixed assets (structures, equipment, and inventories) plus net stock of consumer durables²⁸
5. Labor measure N_t : Average quarterly fraction of total hours worked
6. Real wage measure W_t : Nominal wage divided by the GDP-deflator

²⁵E.g. durables in the period 1970:I-1991:IV. See for instance R  th et al. (2006).

²⁶They derive a quarterly series of the capital stock with a method based on Greenwood et al. (1997), who derived admittedly annual capital stocks.

²⁷As in Cooley and Prescott (1995).

²⁸To that Cooley and Prescott (1995) also add land. They argue that this should as well integrated into the production function, but the data on the stock of land is inadequate and is omitted here.

7. Labor share $1 - \alpha$: Average mean over the sum of total real wage of the dependent employees plus a share of self-employed divided by GDP at factor prices
8. TFP measure Z :
 - i. Based on labor variations only
 - ii. Based on labor and capital variations using the adequate capital measure

4 Results

4.1 Calibration

In consideration with the outlay of estimation methods and that in the "literature on intertemporally optimized models has shown a clear preference for calibrating rather than estimating parameters of interest", as Favero (2001), p. 248, mentions, in this paper the decision falls also to classical or rather traditional calibration. Accordingly calibration simple means "to standardize as a measuring instrument", as Cooley and Prescott (1995), p. 22, or Cooley (1997), p. 58, argue, and this meaning applies to the idea behind calibration of the here considered stochastic growth model.²⁹ Table 4.1 reports the calibrated parameter values at the steady state equations (2.12a), (2.12b), (2.12c), and (2.12d) for the two different subsamples.³⁰

Table 4.1
Calibration of the parameters for the GNIPA data set of the GFSO

1970:I-1991:IV		1991:I-2012:IV	
Production	Preferences	Production	Preferences
$a = 1.006$	$\beta = 0.994$	$a = 1.003$	$\beta = 0.994$
$\alpha = 0.32$	$\eta = 2.0$	$\alpha = 0.34$	$\eta = 2.0$
$\delta = 0.015$	$N = 0.14$	$\delta = 0.017$	$N = 0.12$
$\rho_1 = 0.98$	$\theta = 5.80$	$\rho_1 = 0.97$	$\theta = 6.13$
$\rho_2 = 0.92$		$\rho_2 = 0.83$	
$\sigma_1 = 0.0089$		$\sigma_1 = 0.0086$	
$\sigma_2 = 0.0081$		$\sigma_2 = 0.0082$	

For a comparison of these two subsamples one should hold in mind, that the territorial status is different in these two time periods. Accordingly it comes as no surprise that

²⁹For a more detailed representation of the calibration methodology, see the Appendix.

³⁰See Stock and Watson (1996) and Ireland (2004) for a discussion of parameter instability per se.

changes occur in all variables, apart from η and β which were set.³¹ The time preference parameter β , cannot be calculated by the steady state equations, because this violates the restriction $\beta < 1$ in representative agent models. To simply bypass this problematic value, the time preference parameter is set to 0.994, as in Heer and Maußner (2009).³²

Firstly, the growth rate $(a - 1)$ is inferred from fitting a linear trend to the log of GDP at factor prices per capita. It is a little bit lower for the new time period. This also emphasizes the observed reduction in the growth rate of GDP. These two derived values are in line with the values typically used in such models, see for example Cooley and Prescott (1995), who use $a = 1.00156$, or Gomme and Rupert (2007), who use an average a of 1.005. Secondly, the capital income parameter α , increased from 0.32 to 0.34 or inversely the labor income reduced from 0.68 to 0.66, which suggests a now more capital-intensive economy. In other words, the economy was more labor-intensive in the first time period. This argumentation also corresponds to the statement by Schmalwasser and Schidlowski (2006), who argue that production becomes more capital-intensive, because labor is increasingly replaced by capital and therefore the capital stock grows faster than production. These different values also suggest that a TFP shock affects the labor income share.³³ Further, related to the decline in the growth rates of investments and the capital stock over time, the degree of modernity of the capital stock is reduced.³⁴ For example, Cooley and Prescott (1995) calibrate the parameter α as 0.40, which is greater than the usually used value of 0.36 by, e.g., Kydland and Prescott (1982), Hansen (1985), Prescott (1986) or Maußner (1994),

³¹Hall (1988) shows that a high value of η implies an insensitive consumption growth. For a survey of microeconomic estimates of the coefficient of relative risk aversion, see Mehra and Prescott (1985), who find, "that the bulk of the evidence places its value between 1 and 2", as Gomme and Rupert (2007) on p. 487 mention. The value of 2 is an evidence for a greater consumption smoothing over the life cycle of the households and so this value is set to 2, as in Heer and Maußner (2009). Furthermore, a larger elasticity of the marginal utility of consumption "reduces the variability of output, working hours, and investments, and thus this choice provides a better match between the model and the respective German macroeconomic variables", as Heer and Maußner (2009), p. 51, argue.

³²Prescott (1986), Cooley and Prescott (1995), and Gomme and Rupert (2007) calculate this parameter as $\beta = 0.99$, $\beta = 0.987$, and $\beta = 0.9860$, respectively, so that this value is toward the high end of values typically used in the literature considered here.

³³For this, see Cantore et al. (2013), who examine inter alia this relationship within an RBC and a NK framework.

³⁴This is the ratio of net to gross fixed assets, where this characteristic variable also provides information about the aging process of investment goods and indicates how much percentage of the assets are not impaired by wear or depreciated in value. See Schmalwasser and Schidlowski (2006).

because they included the imputed income of governmental capital. This suggests a more capital-intensive U.S. economy than the German economy. Gomme and Rupert (2007) calibrate the share of capital income as 0.283 and mention on p. 493 that their value "is toward the low end of values typically used in the "RBC/DSGE" literature", such as the value in Heer and Maußner (2009). The values derived above are between these ranges. Furthermore, the U.S. NIPA data is more accurate for determining the income of the capital side, the GNIPA data is more accurate for determining the income of the labor supply side, because the data is very detailed, extensive, and more reliable, and so $1 - \alpha$ is specified here, which equals the average wage share in GDP at factor prices.³⁵ To that it should also be mentioned that this specification as well contemplates the governmental labor income, because the income time series include also public labor and so this approach is more or less identical to the approach by Cooley and Prescott (1995). Thirdly, the average quarterly depreciation rate, δ , has also increased, which suggests a higher depreciation rate for, e.g., communication systems and personal computers. Cooley and Prescott (1995) choose the average depreciation rate as 0.048 yearly or 0.012 quarterly and argue that if an economy does not explicitly include growth these values must be larger in order to match the investment-output ratio. Furthermore, Gomme and Rupert (2007) compute an average depreciation rate of 0.0271 and so the above derived values are also between these two ranges. The preference parameter θ , also increases, suggesting that the households now appreciate leisure more. The observed demographic change in Germany can be explained by the parameter N , which is slightly lower for the period 1991:I till 2012:IV, because the population as a whole grows older. So more people are on pension and no longer participate in the working life, which leads to a reduction of labor supply.³⁶

The parameters of the shock in the period 1970:I-1991:IV with $\rho_1 = 0.98$ and $\sigma_1 = 0.0089$, where only labor input is considered in the Solow residual, and $\rho_2 = 0.92$ and $\sigma_2 = 0.0081$, where labor and capital input are integrated in the Solow residual, are more or less in line with the values normally taken in the literature. For example, Cooley and Prescott (1995) choose, among others, the value 0.95 and Gomme and Rupert (2007) choose the value 0.9641 for the persistence parameter ρ . For the volatility of the shock, σ , Cooley and Prescott (1995) take the value 0.007, Prescott

³⁵As in Heer and Maußner (2009). For this and the different calculation bases for GDP in Germany and the U.S., see again Schmalwasser and Schidlowski (2006) and further Schwarz (2008).

³⁶For a recent analysis of changes in the age composition of the labor force and the connection to BC volatility in the G7 countries, see Jaimovich and Siu (2009) as well as Heer et al. (2013).

(1986) chooses the value 0.00763, and Gomme and Rupert (2007) choose the value 0.0082, who also take consumer durables into account. This indicates that the derived values above are on the top of values typically used for this variable in this literature. Gomme and Rupert (2007) argue that the Solow residual is at best characterized by an autoregressive parameter of 0.9641 and a standard deviation of 0.0082, compared to more standard values of 0.95 and 0.00763, respectively. They further argue that their results are not sensitive, if no capital stock ($\rho = 0.9697$, $\sigma = 0.0081$), one capital stock ($\rho = 0.9643$, $\sigma = 0.0082$), or two capital stocks ($\rho = 0.9641$, $\sigma = 0.0082$) is (are) included, but here this is not the case, as well as the different values demonstrate. For both subsamples this difference is conspicuous for the autoregressive parameter ρ , which falls from 0.98 to 0.92 and from 0.97 to 0.83, if additionally the capital input is included into the Solow residual.³⁷ Also the volatility of the shock, σ , falls from 0.0089 to 0.0081 and from 0.0086 to 0.0082 in both subsamples, respectively. The finding that the shocks in the second subsample are smaller than in the first subsample emphasizes as well the argumentation by Buch et al. (2004), who find the same result for the period till 2001:IV with a counterfactual VAR analysis and call this phenomenon "good luck". In this respect it should also be mentioned that α does not account for a differentiation of these results in the shock process, the working hours also do not matter (only σ is a little bit higher), and only GDP and the capital stock do matter slightly. Also Cooley and Prescott (1995) mention that Prescott (1986) already argues that the volatility of the innovations might be affected by measurement errors in the measured labor input and taking these into account would actually very slightly increase the standard deviation of the innovations to technology, as just mentioned. However, just as Cooley and Prescott (1995) too, we choose to ignore it here and leave it for future research.

4.2 Properties of the Business Cycle

The following table displays the results from the computation of the real economy, where the variables are as defined and constructed in subsection 3.3.

A comparison between the two different subsamples reveals at first that the standard deviation of output is increased from 1.27 to 1.51 and the volatility of durables consumption is reduced by about a half. So it is apparent, on the one hand, that the decline of output volatility in Germany, as it is reported for the period 1970:I-2001:IV

³⁷In their model with all shocks, Gomme and Rupert (2007) set the autoregressive parameter ρ on durables technological change even to 0.9999.

Table 4.2
Estimated Second Moments for the GNIPA data set of the GFSO

Variable	s_x	s_x/s_Y	r_{xY}	r_{xH}	r_x
<u>1970:I-1991:IV</u>					
Output	1.27 (0.21)	1.00	1.00	0.81 (0.11)	0.73
Durables Consumption	6.11 (0.42)	4.81	0.22 (0.12)	0.12 (0.08)	0.09
Non Durables Consumption	0.97 (0.13)	0.76	0.51 (0.14)	0.41 (0.20)	0.47
Gross Fixed Investments	4.12 (0.77)	3.24	0.72 (0.12)	0.75 (0.11)	0.70
Total Gross Fixed Investments	3.62 (0.63)	2.85	0.84 (0.07)	0.70 (0.14)	0.60
Hours	0.96 (0.23)	0.76	0.81 (0.11)	1.00	0.81
Real Wage	0.81 (0.09)	0.64	0.54 (0.15)	0.52 (0.12)	0.32
<u>1991:I-2012:IV</u>					
Output	1.51 (0.50)	1.00	1.00	0.72 (0.16)	0.81
Durables Consumption	3.28 (0.63)	2.17	0.17 (0.26)	0.16 (0.27)	0.27
Non Durables Consumption	0.77 (0.11)	0.51	0.45 (0.14)	0.41 (0.15)	0.58
Gross Fixed Investments	3.99 (0.79)	2.64	0.84 (0.07)	0.75 (0.10)	0.84
Total Gross Fixed Investments	4.35 (1.60)	2.88	0.93 (0.05)	0.69 (0.15)	0.82
Hours	0.93 (0.17)	0.62	0.72 (0.16)	1.00	0.66
Real Wage	0.79 (0.19)	0.52	0.28 (0.20)	0.20 (0.21)	0.72

Notes: s_x :=standard deviation of HP-filtered time series x , where x stands for any of the variables from column 1. s_x/s_Y :=standard deviation of variable x relative to standard deviation of output Y . r_{xY} :=cross-correlation of variable x with output Y , r_{xH} :=cross-correlation of variable x with hours H , r_x :=first-order autocorrelation of variable x . Standard errors based on the quadratic spectral (QS) kernel with prewhitening in parantheses.

by Buch et al. (2004) as well, is not detected for the whole time period.³⁸ Thereto

³⁸However it should be mentioned that Buch et al. (2004) use the Census X-11-ARIMA method for seasonal-adjusting and the HP-Filter with a smoothing parameter of 1000 for detrending, following Pedersen (2001). They argue on p. 454 that their "results were not affected", since they choose a smoothing parameter of 1600, as done in this paper. Admittedly, it is not at all clear what the authors mean by "real GDP", because they do not refer to how they achieve the price-adjusting at all.

it should be mentioned that the reason is the financial crisis during the second subsample and thus, the output decline in Germany is only detected till 2008:IV, since both subsamples are compared with each other as point estimates as done in this paper solely. On the other hand, it is apparent that the reduction of durables volatility is presumably due to better financing opportunities for valuable consumption goods in the second subsample. Also the standard deviation of non-durables consumption decreased from 0.97 to 0.77. The standard deviations of gross fixed investments, total gross fixed investments, which includes all the magnitudes mentioned above, hours, and real wage have not changed significantly. The cross-correlations with output and with hours have overall fallen, apart from the gross fixed investments and the total gross fixed investments time series. A reduction in the autocorrelation is only discerned in the time series of non-durables consumption and hours. The increase in the first-order autocorrelation of real wage is more than a half.

Table 4.3 displays a pairwise test of significance, where the used test statistic is a Wald test statistic, based on the procedure of Maußner (2013a) and displayed in the first row.³⁹ The standard errors are based on the quadratic spectral (QS) kernel with prewhitening, as it was suggested for example by Ogaki (1993).⁴⁰ The respective marginal probability of the null hypothesis of no change in the estimated moments is presented in the second row.

Table 4.3
Test of Significance

	<i>sy1 sy2</i>	<i>scd1 scd2</i>	<i>sc1 sc2</i>	<i>sg1 sg2</i>	<i>sgi1 sgi2</i>	<i>sh1 sh2</i>	<i>sw1 sw2</i>
Wald Statistic	0.142	20.279	0.108	0.039	1.331	0.003	0.001
p-value	0.706	0.000	0.742	0.844	0.249	0.958	0.970

Notes: Abbreviations: *sx1* and *sx2*: standard deviation of variable $x \in \{\text{Output, Durables Consumption, Non Durables Consumption, Gross Fixed Investments, Total Gross Fixed Investments, Hours, Real Wage}\}$ in period 1970:I-1991:IV (1) and 1991:I-2012:IV (2), respectively.

On this occasion it is apparent that only the long-lived durables have changed statistical significant, where all other time series remain unchanged, because the null hypothesis cannot be rejected at all usual levels of significance. With these considerations, one can conclude in this respect, that the nature of the German BC has not changed regarding the standard deviations of the considered magnitudes, except for durable goods.

³⁹See Ogaki (1993) for some critical comments on the Wald test.

⁴⁰For the properties and the automatic bandwidth estimators of the QS, Truncated, Bartlett, Parzen, and Tukey-Hanning kernel, see for example Andrews (1991) and further Andrews and Monahan (1992) for prewhitened kernel estimators.

4.3 Data and Model

Model Implications Table 4.4 displays the findings from the simulation of the artificial benchmark model, where the calibration targets in table 4.1 are used.⁴¹ Of course, the number of observations is the same as the number of quarterly observations as are available for the German economy in the two considered time periods, which are both of the same length and include 88 quarters each.

Table 4.4
Simulated Second Moments for the GNIPA data set of the GFSO

Variable	s_x	s_x/s_Y	r_{xY}	r_{xH}	r_x
<u>1970:I-1991:IV</u>					
Output	1.53	1.00	1.00	0.99	0.66
Consumption	0.64	0.42	0.99	0.97	0.68
Gross Fixed Investments	5.09	3.32	1.00	1.00	0.66
Hours	0.78	0.51	0.99	1.00	0.66
Real Wage	0.76	0.50	0.99	0.98	0.68
<u>1991:I-2012:IV</u>					
Output	1.57	1.00	1.00	1.00	0.61
Consumption	0.55	0.35	0.99	0.97	0.63
Gross Fixed Investments	4.96	3.16	1.00	1.00	0.61
Hours	0.91	0.58	1.00	1.00	0.61
Real Wage	0.67	0.42	0.99	0.98	0.62

Notes: s_x :=standard deviation of HP-filtered simulated time series x , where x stands for any of the variables from column 1, based on 1000 replications with 88 observations each. s_x/s_Y :=standard deviation of variable x relative to standard deviation of output Y . r_{xY} :=cross-correlation of variable x with output Y , r_{xH} :=cross-correlation of variable x with hours H , r_x :=first-order autocorrelation of variable x .

Here it becomes apparent that both cross-correlations are almost identical and the first time period displays slightly higher first-order autocorrelations. However, the cross-correlations are totally at odds compared with the cross-correlations of the real economy. The further comparison between the two subsamples reveals that the volatility of output increases slightly in the simulated model, where the second moments of the real economy show that the standard deviation highly increases between the two subsamples. However, the simulated standard deviation with 1.57 is strictly in line with the volatility of output in the real German economy with 1.51 in the second time period. Such as in the data for non-durables consumption, there is a reduction of the standard deviation of consumption in the artificial benchmark model. The volatility of

⁴¹Only the calibrated parameter values from the Solow residual with labor and capital input in subsection 4.1 are used here.

gross fixed investments and real wage has also fallen slightly between these two subsamples in the model. But since table 4.4 displays that the volatility of gross fixed investments falls and table 4.2 displays a rise in total gross fixed investments, this can only be explained by a slight decrease of gross fixed investments and mainly by a decrease of durables consumption, which falls from 6.11 to 3.28 as shown in table 4.2.⁴² This change of about a half, keeping in mind table 4.3, is therefore significant as well. Also the volatilities of hours and real wage only show a small decrease from the period 1970:I-1991:IV to the period 1991:I-2012:IV for the real German economy. The simulated standard deviation of hours behaves contrary to the data, because in the artificial economy the volatility increases from 0.78 to 0.91 and in the real economy the volatility decreases from 0.96 to 0.93. Though for this statement one should hold in mind the results in table 4.3, where the changes of hours in the data are not significant. Apart from this, one explanation for this counterfactual result could be that there is less change in the number employed in data than in the artificial economy, which does not account for changes into and out of the labor market so that all variability in hours is not due to fluctuations in the number employed, but in hours worked.⁴³ The standard deviation of real wages decreases stronger in the model than in the data, but this direction however is in line with the derived results above.

Model Evaluation Since we now focus on the evaluation of the model in both time periods respectively, the structural break within the German reunification will not be explicitly contemplated.⁴⁴ In line with the suggestion of Krämer (2011), pp. 463-464, that it "should be standard practice" to test "whether the model that is entertained provides a proper approximation to the data", the simulated model will be evaluated as follows.⁴⁵

The straightforward measurement is the Euclidean distance, where the weighting matrix is the identity matrix. Since in this measurement there is no consideration of

⁴²However, one should hold in mind that the standard error of total gross fixed investments is 1.60 in the second subsample for the GNIPA data set of the GFSO.

⁴³A more accurate mapping of the labor market in the model framework may explain these different results. For this, see also Hansen (1985) and Rogerson (1988).

⁴⁴As also mentioned in the Appendix. Therefore there is no use of tests with a known break point, such as the popular Chow test, or with an unknown break point, such as the different CUSUM tests. For the latter, their extensions, and their asymptotic features, see for example Krämer et al. (1988) or Ploberger et al. (1989).

⁴⁵Of course, for this purpose there exist manifold opportunities. See for instance the Appendix.

the respective standard errors, and taking into account the estimation errors, another weighting matrix should be used, because moments with small variance should be weighted more than moments with higher variance. One possibility to estimate such a weighting matrix is a general method of moments (GMM) approach, which uses only information contained in the first and second order moments of the data. In this approach "the moments are weighted so as to minimize the covariance matrix of the estimator, or, in other words, to maximize the information content of the used moments", as Iskrev (2013), p. 15, mentions. And "besides testing for stability, the estimated covariance matrix of the second moments [...] can also be used as a weighting matrix in a score statistic that measures how close a simulated DSGE model replicates a set of stylized facts", as Maußner (2013a), pp. 11-12, mentions. For the standard errors Maußner (2013a) employs five different estimates:

- standard errors that assume uncorrelated disturbances,
- standard errors based on the QS kernel with and without prewhitening, and
- standard errors based on the Bartlett kernel with and without prewhitening.

To comprehensively summarize the information in a set of empirical moments and simulated ones such a score is displayed in the next table.

Table 4.5
Distance Test of the Data and the Model

	<i>ED</i>	<i>AR = 0</i>	<i>QS</i>	<i>QSpw</i>	<i>B</i>	<i>Bpw</i>
			<u>1970:I-1991:IV</u>			
Score	1.858	20.599	71.160	71.430	71.419	70.771
			<u>1991:I-2012:IV</u>			
Score	1.530	11.332	98.385	96.635	85.044	84.897

Notes: Abbreviations: *ED*: Euclidean distance *AR = 0*: standard errors without correction for autocorrelation, *QS*, *B* standard errors from the quadratic spectral and Bartlett kernel, respectively, *pw*: with prewhitening.

In table 4.5, in which the measures for the difference between the moments estimated from the data and the moments obtained from the simulated model, or in other words, the measures for the distance between the data and the model are reported, our attention is focused on the time series discussed above: seasonal- and calendar-adjusted quarterly real GDP, consumption of non-durables, total gross fixed investments, hours, and real wage in both subsamples each. The focus is on the regarding standard deviation, the cross-correlation with output, and the cross-correlation with hours. With

these considerations the benchmark RBC model possesses a better match to the real economy regarding the considered second moments in the first time period than in the second, except for the Euclidean distance measure and the measure where the standard errors assume uncorrelated disturbances.

5 Conclusion

In this paper, a benchmark RBC model was considered to look at the BC prior and after the territorial status of the Federal Republic of Germany in 1990. The model consistent data was obtained from the entire period between 1970:I and 2012:IV. The major findings are: i) that the volatility of most aggregate time series has not changed significantly between the two time periods, ii) that despite many conceptual differences between the European and the U.S. System of Accounts, the calibrated parameter values for the German economy are within the range of values usually employed in the RBC literature, iii) that the model is closer to the data for the time period prior to reunification.

Although the data pre-adjustment resulted in that the model delineates the data quite well, the model is far from perfect. Thus model extensions could be fruitful for a more detailed explanation of the BC in Germany. For example, more than one shock could be considered to see how additional shocks (e.g. a preference shock to uncover the cross-correlation between hours and real wage and/or a government spending shock to achieve a more elaborated theoretical framework) interact, because in reality "there may be additional shocks".⁴⁶ A further contemplation could also be to integrate leasing as a meanwhile important part in gross fixed investments and thus also in the capital stock.⁴⁷ Another model framework, such as the mentioned NK models in section 1 or a combination of both models, could also be more fertile than the simple benchmark RBC model considered here. Naturally, such extensions are in mind for further research.

⁴⁶Heer and Maußner (2009), p. 59. Here it should be mentioned that Cooley and Prescott (1995) argue by virtue of their result that the standard deviation of GNP in data is greater than in the model, is a hint for more than one shock which drives the economy, but here this is not the case. This argumentation however is only consistent if GNP rather than GDP is imposed. In this respect, see also the corresponding result in Gomme and Rupert (2007).

⁴⁷For this, see Städtler (2002) and Schmalwasser et al. (2011).

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