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## Long-run sectoral development time series evidence for the German economy

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# JENA ECONOMIC RESEARCH PAPERS



# 2008 – 013

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# Long-Run Sectoral Development

## Time Series Evidence for the German Economy

by

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### Abstract

In economic development, long-run structural change among the three main sectors of an economy follows a typical pattern with the primary sector (agriculture, mining) first dominating, followed by the secondary sector (manufacturing) and finally by the tertiary sector (services) in terms of employment and value added. We reconsider the verbal theoretical work of Fourastié and build a simple model encompassing its main features, most notably the macroeconomic influences on the sectoral development. Estimation and analysis with German data for the period 1850-2001 show that this model is quite capable to replicate the empirical facts.

JEL classification: L16, O14, O41

keywords: structural change, industrialization, tertiarization

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## 1. Introduction

The analysis of long-run structural change is concerned with the differential development of the three main sectors of the private economy. This research intends to explain the successive dominance of the so-called primary (agriculture, mining), secondary (manufacturing, construction), and tertiary (services) sectors in terms of employment and value added of an economy. In the literature there are several early accounts and explanations for this pattern of sectoral development, given by Fisher (1939, 1952), Clark (1957) and Wolfe (1955), as well as more recent approaches to integrate the sectoral development into formal growth theory; see inter alia Echevarria (1997), Kongsamut et al. (2001) and Ngai and Pissarides (2007).

A frequently neglected but particularly appealing explanation for long-run sectoral development of the three sectors is given by Fourastié (1949/69).<sup>2</sup> In his book, Fourastié verbally develops a broad theory of economic development involving psychological and sociological elements supplementing the economic considerations. On the supply side, the final effect of technological process is to increase aggregate income. On the demand side, a hierarchy of needs is associated with different saturation levels for the goods of the three sectors. In the course of increasing income, the demand for goods of the primary sector is first saturated. Further increases of income lead to a saturation of the demand for goods of the secondary sector. According to Fourastié, only the demand for goods of the tertiary sector will never be saturated. Accordingly, the demand side determines the direction of structural change.

In this paper, we reconsider the Fourastiéian perspective of long-run structural development. Therefore, we compress this wealth of insights into a simple theoretical framework, emphasizing the interaction of supply-side and demand-side forces for shaping the characteristic pattern of structural change among the primary, secondary and tertiary sector. To perform the empirical analysis a data set has been assembled for the German economy that spans the relevant time period starting from 1850 to the present. Structure is represented by the division of total employment and value added among the primary, secondary and tertiary sector. In constructing the data set, substantial effort has been undertaken to obtain consistent annual time series.

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<sup>2</sup> Notice that the year 1949 refers to the original first edition published in French language and the year 1969 refers to the second edition in German language available to us.

The empirical results show that the very simple theoretical model is quite able to replicate the characteristic pattern of sectoral development. This comprises not only the monotonically declining share of the primary sector and the monotonically rising share of the tertiary sector, but also the inverse U-shaped trajectory of the secondary sector. By that the model covers the period of industrialization as well as the subsequent period of tertiarization. In the case of employment, a major role in achieving this fit is played by the growth rate of aggregate income represented by GDP. For value added the results are less conclusive. Taken together, however, the results reported in this paper show that the consideration of macroeconomic growth in explaining long-run sectoral development improves the statistical account of sectoral dynamics substantially. We interpret this as evidence in favor of the theory of Fourastié, at least in the simplified version we employ here.

The plan of the paper is as follows: The following section 2 outlines a simple theoretical reasoning to motivate the empirical analysis. Section 3 explains the estimation and model evaluation strategy as well as the data set. This section also summarizes the results of an extensive testing for unit roots (the detailed results of which are relegated to an appendix). The empirical results for structural change in terms of employment and value added are then discussed in sections 4 and 5, respectively. Section 6 concludes with a summary of the main results and points to some ways for extending the analysis that we plan to pursue in future work.

## **2. Theoretical Motivation**

To motivate the empirical analyses in the subsequent section we develop here a stylized log-linear formulation of structural change with both demand and supply side considerations. On the demand side, consumer preferences determine a saturation level for the consumption in a sector  $i$ , with  $i \in \{1,2,3\}$  denoting either the primary, secondary or tertiary sector, towards which the consumers plan to adjust their consumption levels. This planned growth of consumption is directly associated with a certain growth rate of labor requirements. On the supply side, labor is the single production factor and changes of wage differentials induce labor flows between the sectors. Demand and supply side changes are assumed to be coordinated by markets in a way that the realized changes in labor input and produced output

are somewhere in between the plans of consumers and producers. This is not necessarily associated with an equilibrium situation in which both plans are equalized.

Starting on the demand side and considering a particular sector  $i$ ,  $i \in \{1, 2, 3\}$ , we assume that the planned growth rate of demand in sector  $i$  at time  $t$ ,  $\ln Y_{it}^d - \ln Y_{it-1}$ , depends on the deviation of the realized demand in the previous period  $Y_{it-1}$  from its saturation (target) level  $\bar{Y}_{it}$ . This leads to a formulation of the partial adjustment model in logs

$$\ln Y_{it}^d - \ln Y_{it-1} = \gamma_i \cdot (\ln \bar{Y}_{it} - \ln Y_{it-1}),$$

with  $\gamma_i \in (0, 1)$  denoting the adjustment speed.<sup>3</sup>

We further assume that the target levels of the sector depends on the aggregate level of economic activity, represented by the lagged level of GDP,  $Y_{t-1}$ , via  $\ln \bar{Y}_{it} = \alpha_i + \beta_i \ln Y_{t-1}$ . Here,  $\alpha_i$  and  $\beta_i$  are sector-specific parameters that can be interpreted as reflecting consumer preferences for the goods of the sector. Given that, the partial adjustment equation can be reformulated leading to

$$\ln Y_{it}^d - \ln Y_{it-1} = \gamma_i \cdot (\alpha_i + \beta_i \ln Y_{t-1} - \ln Y_{it-1})$$

and therefore

$$\ln Y_{it}^d = \gamma_i \alpha_i + \gamma_i \beta_i \ln Y_{t-1} + (1 - \gamma_i) \ln Y_{it-1}.$$

Taking first differences gives

$$\Delta \ln Y_{it}^d = \gamma_i \beta_i \Delta \ln Y_{t-1} + (1 - \gamma_i) \Delta \ln Y_{it-1},$$

where  $\Delta$  denotes the usual first-difference operator defined by  $\Delta x_t = x_t - x_{t-1}$ .

The supply side is represented by the production functions  $\ln Y_{it} = \ln A_{it} + \varphi_i \ln L_{it}$ , where  $L_{it}$  denotes labor input of sector  $i$  in period  $t$ ,  $\varphi_i > 0$  is an elasticity parameter governing returns to scale and  $A_{it}$  represents the sector-specific technology level. In general, it is to be expected that returns to scale are more pronounced in the secondary and the tertiary sector since externalities originating from capital accumulation as emphasized in growth theory (Romer 1986, Lucas 1988) or from the agglomeration of those activities in cities (Lucas and Rossi-

Hansberg 2002, Eeckhout 2004) naturally play a much larger role in these sectors compared to the primary sector.

To satisfy the planned demand growth, output in each sector needs to be increased by a certain rate which can be achieved if there is sufficient technological progress leading to  $\Delta \ln A_{it} > 0$  and/or labor input in the sector increases at a sufficiently high rate

$$\Delta \ln L_{it}^d = \varphi_i^{-1} \cdot (\Delta \ln Y_{it}^d - \Delta \ln A_{it}).$$

Substituting for  $\Delta \ln Y_{it}^d$  gives

$$\Delta \ln L_{it}^d = \varphi_i^{-1} \cdot (\gamma_i \beta_i \Delta \ln Y_{t-1} + (1 - \gamma_i) \Delta \ln Y_{it-1} - \Delta \ln A_{it})$$

and substituting for the lagged growth rate of sector output by the production function leads to

$$\Delta \ln L_{it}^d = \varphi_i^{-1} \cdot (\gamma_i \beta_i \Delta \ln Y_{t-1} + (1 - \gamma_i) (\Delta \ln A_{it-1} + \varphi_i \Delta \ln L_{it-1}) - \Delta \ln A_{it}).$$

Assuming a constant but sector-specific technological progress rate  $g_i = \Delta \ln A_{it} = \Delta \ln A_{it-1}$  we obtain

$$\Delta \ln L_{it}^d = -\varphi_i^{-1} \gamma_i g_i + (1 - \gamma_i) \Delta \ln L_{it-1} + \varphi_i^{-1} \gamma_i \beta_i \Delta \ln Y_{t-1}.$$

Labor input either grows because the population grows or as a result of reallocation of workers between sectors. The growth rate of labor supply in sector  $i$ , as planned on the supply side, is therefore affected by the rate of population growth and growth differentials of wages. Population grows at the rate  $\Delta \ln L_t$ . The wage differential is induced by initial period differences in sectoral labor productivity ( $\ln Y_{it-1} - \ln L_{it-1} = \ln A_{it-1} + (\varphi_i - 1) \ln L_{it-1}$ ) to economy-wide labor productivity  $\ln Y_{t-1} - \ln L_{t-1}$ . This gives rise to the growth differential of labor productivity  $\Delta \ln A_{it-1} + (\varphi_i - 1) \Delta \ln L_{it-1} - (\Delta \ln Y_{t-1} - \Delta \ln L_{t-1})$ . Therefore the planned growth of labor supply in sector  $i$  is,

$$\Delta \ln L_{it}^s = \Delta \ln L_{t-1} + \eta_i (g_i + (\varphi_i - 1) \Delta \ln L_{it-1} - (\Delta \ln Y_{t-1} - \Delta \ln L_{t-1})),$$

where  $\eta_i > 0$  is an adjustment speed parameter.

The third element is to assume that markets are sufficiently working to coordinate the plans from the demand side and the supply side. A very weak implication of this is that the resulting

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<sup>3</sup> Note that the demand of period  $t$  is a planned magnitude (indicated by the superscript  $d$ ) whereas the demand of the previous period is of course a realized magnitude.

labor input in sector  $i$  lies somewhere between the plans from the demand and supply sides. Formally this can be stated by letting the realized labor input (which is observable in the data) in sector  $i$  be a convex combination of  $\ln L_{it}^d$  and  $\ln L_{it}^s$ , i.e.  $\ln L_{it} = \lambda \ln L_{it}^d + (1 - \lambda) \ln L_{it}^s$  with  $\lambda \in [0, 1]$ . Since this does not necessarily imply the equalization of demand and supply it is perfectly compatible with disequilibrium situations without excluding the possibility of equilibrium.

Expressed again in growth rates, these considerations lead us to

$$\begin{aligned} \Delta \ln L_{it} &= \lambda \Delta \ln L_{it}^d + (1 - \lambda) \Delta \ln L_{it}^s \\ &= \lambda \left[ -\varphi_i^{-1} \gamma_i g_i + (1 - \gamma_i) \Delta \ln L_{it-1} + \varphi_i^{-1} \gamma_i \beta_i \Delta \ln Y_{t-1} \right] \\ &\quad + (1 - \lambda) \left[ \Delta \ln L_{t-1} + \eta_i (g_i + (\varphi_i - 1) \Delta \ln L_{it-1} - (\Delta \ln Y_{t-1} - \Delta \ln L_{t-1})) \right] \\ &= (\eta_i - \lambda(\eta_i + \varphi_i^{-1} \gamma_i)) g_i + (\lambda(1 - \gamma_i) + (1 - \lambda)\eta_i(\varphi_i - 1)) \Delta \ln L_{it-1} \\ &\quad + (\lambda(\varphi_i^{-1} \gamma_i \beta_i + \eta_i) - \eta_i) \Delta \ln Y_{t-1} + (1 - \lambda)(1 + \eta_i) \Delta \ln L_{t-1} \\ &= \theta_{i1} + \theta_{i2} \Delta \ln L_{it-1} + \theta_{i3} \Delta \ln Y_{t-1} + \theta_{i4} \Delta \ln L_{t-1} \end{aligned}$$

with obvious definitions of the parameters  $\theta_{i1}$  to  $\theta_{i4}$ . This equation represents an autoregressive process in logs for the growth rate of labor input in sector  $i$  with the lagged growth rates of aggregate GDP and population as intervening variables. The parameters  $\theta_{i1}$  to  $\theta_{i4}$  depend on the structural model parameters in a very complex way so that the structural parameters unfortunately can not be recovered from estimates of  $\theta_{i1}$  to  $\theta_{i4}$ .

The corresponding change of sectoral output can be found by substituting  $\Delta \ln L_{it} = \varphi_i^{-1} \cdot (\Delta \ln Y_{it} - g_i)$  and rearranging:

$$\begin{aligned} \Delta \ln Y_{it} &= (1 - \lambda)(1 + \eta_i) g_i + (\lambda(1 - \gamma_i) + (1 - \lambda)\eta_i(\varphi_i - 1)) \Delta \ln Y_{it-1} \\ &\quad + (\lambda(\gamma_i \beta_i + \varphi_i \eta_i) - \varphi_i \eta_i) \Delta \ln Y_{t-1} + \varphi_i (1 - \lambda)(1 + \eta_i) \Delta \ln L_{t-1} \\ &= \tilde{\theta}_{i1} + \tilde{\theta}_{i2} \Delta \ln Y_{it-1} + \tilde{\theta}_{i3} \Delta \ln Y_{t-1} + \tilde{\theta}_{i4} \Delta \ln L_{t-1} \end{aligned}$$

with the parameters  $\tilde{\theta}_{i1}$  to  $\tilde{\theta}_{i4}$  to be estimated. This output variable resembles a value-added measure which data are available.

As mentioned in the introduction, the model comprises central elements of Fourastié's theory of structural change among the three main sectors of the economy (Fourastié 1949/69). According to Fourastié technological progress leads to increases in labor productivity which affect the three sectors differentially. In our model this is reflected in the sector-specific



values of  $g_i$  and  $\varphi_i$ . These differential increases of labor productivity are associated with decreasing product prices and simultaneously contribute to the increase of overall income. The rising overall income, which we equate to GDP growth, allows the consumers to buy new products that tend to be produced in other sectors (meaning products of the secondary sector instead of the primary sector or products of the tertiary sector instead of the secondary sector). By that, all three sectors successively reach their saturation levels, the primary sector first, followed by the secondary sector. Fourastié assumes that demand for the products of the tertiary sector never becomes saturated. In our model this saturation is captured by the partial-adjustment formulation for product demand. The change of the demand structure needs to be accommodated by the change of the production structure and this is inevitably associated with labor reallocation between the sectors which is a further central element in our model. In sum, technological progress raises aggregate income leading to changes of the production and employment structure as a cause of changes in the structure of consumption.

### 3. Estimation Strategy and Data

The equations for both employment growth and value-added growth for the three sectors, each together with the restriction that the sector values add up to the total, constitute a system. Subsequently, the model equations for employment (and likewise for value added) are estimated as a two-equation system of seemingly unrelated regression equations (SURE, Zellner (1962)) with updating coefficients and the weighting matrix simultaneously at each iteration. The system is specified by two equations for the primary and the secondary sector with the additional restriction that all three sectors add up to the total. From a statistical point of view, a very fortunate feature of the model is that all variables in the system are expressed in growth rates, thereby avoiding spurious regressions (Phillips 1986). This will become clear shortly when we discuss the results of our unit-root and stationarity analysis. Moreover, all explanatory variables appear with a lag and are thus less prone to endogeneity.<sup>4</sup>

To reach a judgement about the appropriateness of the model to replicate the typical pattern of long-run structural change among the three sectors, it is not sufficient to have estimates for a model in growth rates. Therefore, our strategy to evaluate the explanatory power of the model is first to estimate the SURE system and then to solve it numerically for the development of

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<sup>4</sup> The model equations look related to a first-order vector autoregression and indeed the estimation of such a system leads to similar results.

the sector shares of either total employment or total value added in a second step. The algorithm used is Gauss-Seidel (see Judd 1998, p. 72) for computing the dynamic solution of the model which actually amounts to a multi-step forecast where the forecasted values of the endogenous variables itself are used for their lags in later periods. The final judgement of the goodness-of-fit of the model relies on comparing the solution trajectories to the actual development.

The data we use are compiled from various sources. Sectoral employment is measured by the number of employed persons (including paid employees, self-employed persons and unpaid family workers). The value added series we use actually represents real net value added to factor cost. For the period before 1950 our primary data source is Hoffmann (1965). Employment data in the period since 1950 are taken from the 10-Sectoral Database (1950-1991) and the 60-Industry Database (1992-2001) of the Groningen Growth and Development Centre (GGDC, see O'Mahony and van Ark (2003) and van Ark (1996)). Value added data since 1950 are taken from the national accounts provided by the German federal statistical office (Statistisches Bundesamt). For the calculation of the value added series three different variants have been implemented. The details of these variants and for the various operations undertaken to reach the final set of our sectoral data are described in appendix A. The macroeconomic time series for real GDP and population are taken from Angus Maddison's web page (see Maddison 2007).

The data for employment span the period 1878-2001, whereas the data for value added span the period 1850-2001. By that our sample period starts in the mid of the 19th century, when the industrial revolution in Germany began (see e.g. Galor (2005), Maddison (1991)).<sup>5</sup>

Unfortunately, for both variables and all three sectors two substantial data gaps appear around the two world wars, so that data are missing for the years 1914-1924 for both variables and 1945-1949 (1939-1949) for employment (value added). To deal with this problem we opted for omitting the whole period 1914-1949 and taking account for this by permitting a structural break in the estimates. This is done by allowing for a break in the mean growth rates and later on a break in the deterministic trend in the growth rates (i.e. by defining a dummy variable

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<sup>5</sup> As an example, in 1835 the first German railway train went from Nürnberg to Fürth. Economically important was the railroad between Leipzig and Dresden opened in 1837. Along with the railroadization the demand for metal and steel products increased and could be satisfied by the rising industrial sector which was increasingly equipped with steam engines. In Germany, the industrial sector was quantitatively dominating until 1960 (see Bairoch 1982, table 4 on p. 281).

post1950 equal to unity for all years since 1950 and zero otherwise). By that possible inaccuracies from the necessary currency conversion to the Deutsche Mark are also alleviated.

The usage of interpolation and imputation methods appears to be dangerous in this case because two 11 year blocks of data are missing and moreover the existing data for the period 1925-1938 are deemed to be particularly unreliable because of the very turbulent political and economic environment during these years including major crises such as the German hyperinflation 1922-23 and the world economic crisis 1929-33 (the German expression for the great depression in the US).

Since the validity of our statistical estimates depends on the order of integration of the data series used we have extensively tested for unit roots and stationarity. Detailed tables of the results are shown in appendix B and are just summarized here for brevity. Nearly all of the unit-root tests are not able to reject their null hypothesis for the (logged) level series whereas the stationarity tests vividly reject their reverse null hypothesis. Thus, all variables used for the estimates, the growth rates of sectoral employment and value added as well as the growth rates of economy-wide GDP and population are treated as stationary. This also holds when structural breaks in various forms are permitted in the tests.

#### **4. Results for Employment**

For structural change in terms of employment the results of three model specifications are shown in table 1. Specification A1 is a first-order autoregressive process for the employment growth rates augmented by a structural break in the intercept. In specification B1, the macroeconomic variables, the lagged growth rates of real GDP and population, are included. This specification is closest to the theoretically motivated equation derived above. Specification C1 amounts to a further inclusion of a linear deterministic trend with a possible structural break.

Table 1  
Results for Employment

Specification	A1		B1		C1	
Dep. Var.	$\Delta \ln L_{1t}$	$\Delta \ln L_{2t}$	$\Delta \ln L_{1t}$	$\Delta \ln L_{2t}$	$\Delta \ln L_{1t}$	$\Delta \ln L_{2t}$
Sector	primary	secondary	primary	secondary	primary	secondary
Intercept	0.004 (0.563)	0.012 (2.582)	-0.005 (-0.315)	0.003 (0.315)	-0.011 (-0.357)	0.017 (0.912)
$\Delta \ln L_{it-1}$	0.201 (2.274)	0.381 (4.758)	0.122 (1.336)	0.191 (2.074)	0.072 (0.798)	0.158 (1.685)
$\Delta \ln Y_{t-1}$			0.204 (1.072)	0.474 (3.919)	0.486 (2.157)	0.553 (3.785)
$\Delta \ln L_{t-1}$			0.349 (0.261)	-0.012 (-0.015)	1.240 (0.878)	0.474 (0.531)
post1950	-0.030 (-3.066)	-0.010 (-1.715)	-0.032 (-2.104)	-0.017 (-1.911)	-0.184 (-2.421)	-0.062 (-1.361)
time					0.000 (-0.408)	0.000 (-1.087)
time:post1950					0.001 (1.499)	0.001 (1.181)
<i>N</i>	86	86	86	86	86	86
$R^2$	0.097	0.134	0.121	0.268	0.160	0.266
<i>dw</i>	2.524	2.205	2.328	1.985	2.279	1.979
$Q(1)$	5.486 (0.019)	0.855 (0.355)	2.040 (0.153)	0.008 (0.929)	1.501 (0.221)	0.015 (0.904)
$Q(4)$	7.961 (0.093)	1.293 (0.863)	4.231 (0.376)	0.578 (0.966)	5.113 (0.276)	1.038 (0.904)

Note: estimated as SURE system with the additional restriction that the sectors add up to the total; t-statistics are reported in parentheses below the coefficients; *N* denotes sample size;  $R^2$  is reported in the corrected version; *dw* is the Durbin-Watson statistic;  $Q(1)$  and  $Q(4)$  are the Box-Ljung statistics for one and four lags, respectively, with the associated p-values in parentheses.

In the table the coefficient estimates with their t-statistics in parentheses are reported above the dashed line. Below the dashed line the corrected version of  $R^2$ , the Durbin-Watson statistic *dw* and the Box-Ljung portmanteau statistics for one and four lags,  $Q(1)$  and  $Q(4)$ , with their p-values in parentheses are presented. The latter two statistics test for autocorrelation and are used for model validation, whereas the Durbin-Watson statistic is not reliable in the presence of a lagged dependent variable.

The results for specification A1 show significantly positive estimates for the parameters of the lagged dependent variables. They reveal moderate autoregressive dependence in both sectors, a bit stronger in the secondary sector. The impact of the structural break in the intercept is significant on a 5 percent level of significance only in the primary sector. However, residual autocorrelation appears to be a problem in the equation for the primary sector.

Once the macroeconomic variables are introduced in specification B1, the degree of autoregressive dependence becomes weaker and remains significant only in the case of the secondary sector. GDP growth acts positively in both sectors, but is significantly so only in the secondary sector. Population growth, by contrast, is never significant. Nevertheless, the introduction of the macroeconomic variables is suited to increase the explanatory power of both equations and furthermore removes residual autocorrelation.

As mentioned already above, specification B1 is closest to our theoretical considerations. Therefore we now have a closer look at the numerical values of the parameter estimates. Starting with the coefficient pertaining to  $\Delta \ln L_{t-1}$  we observe insignificant values for both the primary and the secondary sector. This coefficient is equal to  $(1-\lambda)(1+\eta_i)$  and becomes close to zero only if  $\lambda$  is close to its upper bound of unity. Taken literally, this implies that it is the demand side that dominates labor force reallocations between the sectors as postulated by Fourastié. This finding has implications for the other parameter estimates. With  $\lambda$  close to unity the coefficient pertaining to  $\Delta \ln L_{it-1}$  is close to  $1-\gamma_i$  which should be between zero and unity and the coefficient pertaining to  $\Delta \ln Y_{t-1}$  is close to  $\varphi_i^{-1}\gamma_i\beta_i$  which should be positive. The corresponding parameter estimates lie indeed in these ranges, although significantly so only in the case of the secondary sector, and are thus in support of this interpretation.

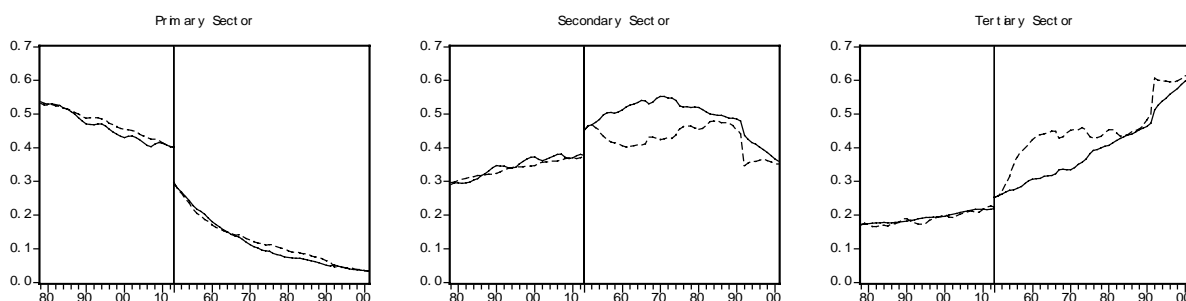
In specification C1 a deterministic trend with a possible structural break is added, leading to a further weakening of the autoregressive dependence. Now, GDP growth has a significantly positive effect in both sectors, whereas population growth remains insignificant. Residual autocorrelation is also no problem in this specification. Common in all three specifications A1, B1 and C1 is that autoregressive dependence appears to be stronger in the secondary sector. In B1 and C1 the positive effect of GDP growth is also stronger in the secondary sector, whereas the effect of population growth is stronger in the primary sector (although not statistically significant). The structural break between 1913 and 1950 is associated with a shift of the intercept but not with a change of a deterministic trend. The latter fact is not overly surprising since all variables used appear to be stationary.

Additional results, not reported in this paper, support these general findings and can be briefly summarized as follows: First, the introduction of the broken deterministic trend in the otherwise pure autoregressive specification without the macro-variables is associated with a weakening of the autoregressive dependence without being suited to remove residual

autocorrelation. Second, in cases where either GDP growth or population growth is considered in isolation (without a deterministic trend) only GDP growth appears significant. This variable increases explanatory recognizably and also removes residual autocorrelation. Third, in contrast to the dummy variable post1950, introducing a blip dummy (equal to unity for the first year after the break and zero otherwise) was not able to account for the possible structural break sufficiently. It was never significant and did not improve explanatory power.

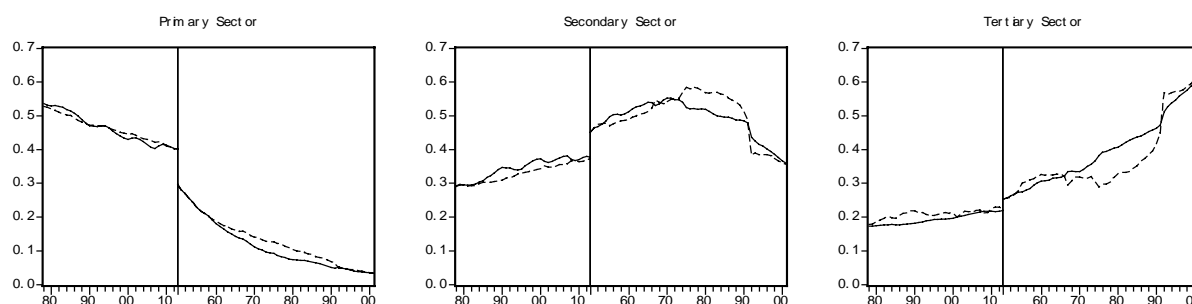
To judge the ability of the estimates in table 1 to replicate the typical development of the sector shares in total employment, the following figures 1 to 3 plot the realized time paths of the shares of the primary, secondary and tertiary sectors (from left to right) as the solid lines, together with the solution paths (numerically computed by Gauss-Seidel as remarked above) as the dashed lines. Starting with specification A1, figure 1 shows the specification is quite good in explaining the monotonically declining employment share of the primary sector, but has difficulties with explaining the developments of the secondary and tertiary sectors after World War Two. This is reflected in the goodness-of-fit measures of 0.996, 0.779 and 0.910 for the primary, secondary and tertiary sectors, respectively, computed as the squared correlation coefficients of the realized share path and the associated numerical solution.

Figure 1  
Employment Shares with Solution from Specification A1



Introducing the macro variables as suggested by the theoretical model improves the fit of the numerical solution substantially as figure 2 for specification B1 shows. This holds especially for the secondary sector, where the inverse U-shaped form of the time path is now tracked quite closely by the numerical solution, except for the period starting in the mid of the 1970s to the start of the 1990s. Goodness-of-fit is here 0.996, 0.925 and 0.902 for the primary, secondary and tertiary sectors, respectively.

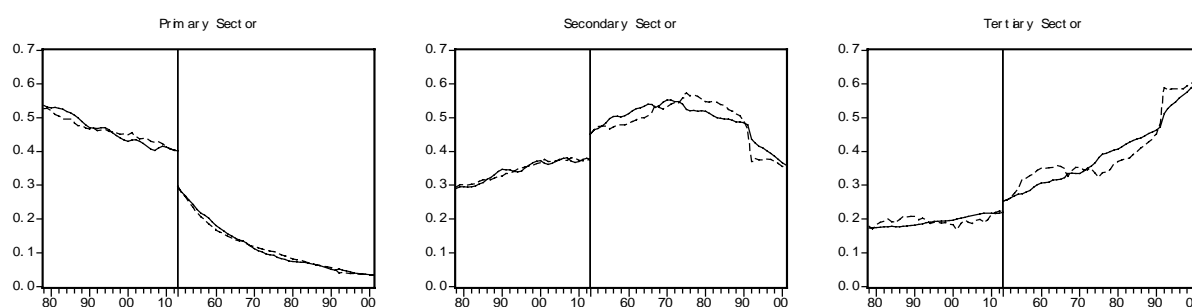
Figure 2  
Employment Shares with Solution from Specification B1



The rather surprising fact of this solution is that although we have only growth rates included into the specification, the numerical solution is indeed able not only to replicate the monotonically decreasing or increasing paths of the primary and tertiary sectors, but it is also suited to replicated the more challenging path of the secondary sector with its inflexion point.

In specification C1 a deterministic trend with a break is added and leads to the solution depicted in figure 3 as the dashed line. The figure shows that introducing a deterministic trend component is associated with a further improvement of fit. This is also reflected in the goodness-of-fit measures of 0.996, 0.933 and 0.950 for the primary, secondary and tertiary sectors, respectively.

Figure 3  
Employment Shares with Solution from Specification C1



In sum, the results show that whereas the autoregressive specification in A1 has some difficulties in replicating the sector shares, the explanatory power improves considerably once the macroeconomic variables are introduced in specification B1, as suggested by Fourastié and by the theoretical model. In further results, not reported here, we introduced the growth rates of the macroeconomic variables after extracting the long-run component of GDP and population by the Hodrick-Prescott filter (Hodrick and Prescott 1997). This modification was associated with an even better fit but the filtering may induce an endogeneity problem so that

we decided not to report the details. The introduction of a deterministic trend component in specification C1 improved the fit only slightly, which is not overly surprising in the light of the small and insignificant coefficients of these regressors.

## 5. Results for Value Added

In this section we report the corresponding results for value added in table 2. The specifications are autoregressive processes for the value added growth rate analogously to those in the previous section.

Table 2  
Results for Value Added

Specification	A2		B2		C2	
Dep.Var.	$\Delta \ln Y_{1t}$	$\Delta \ln Y_{2t}$	$\Delta \ln Y_{1t}$	$\Delta \ln Y_{2t}$	$\Delta \ln Y_{1t}$	$\Delta \ln Y_{2t}$
Sector	primary	secondary	primary	secondary	primary	secondary
Intercept	0.021 (3.510)	0.028 (4.583)	0.020 (1.447)	0.023 (1.849)	0.030 (2.039)	0.038 (3.045)
$\Delta \ln Y_{it-1}$	-0.190 (-2.257)	0.250 (3.081)	-0.265 (-2.527)	0.150 (1.296)	-0.255 (-2.446)	0.057 (0.510)
$\Delta \ln Y_{t-1}$			0.297 (1.397)	0.292 (1.359)	0.052 (0.226)	0.043 (0.210)
$\Delta \ln L_{t-1}$			-0.458 (-0.381)	0.157 (0.144)	-1.404 (-0.996)	-1.350 (-1.117)
post1950	0.008 (0.917)	0.018 (2.120)	0.003 (0.234)	0.019 (1.626)	0.177 (2.585)	0.297 (4.910)
time					0.000 (0.480)	0.000 (0.975)
time·post1950					-0.002 (-2.180)	-0.002 (-4.055)
<i>N</i>	112	112	112	112	112	112
$R^2$	0.025	0.147	0.025	0.140	0.066	0.265
<i>dw</i>	2.101	1.937	2.152	1.948	2.156	1.954
$Q(1)$	0.589 (0.443)	0.139 (0.710)	1.044 (0.307)	0.093 (0.760)	0.876 (0.349)	0.103 (0.749)
$Q(4)$	1.959 (0.743)	1.396 (0.845)	2.238 (0.692)	1.031 (0.905)	3.373 (0.497)	3.143 (0.534)

Note: estimated as SURE system with the additional restriction that the sectors add up to the total; t-statistics are reported in parentheses below the coefficients; *N* denotes sample size;  $R^2$  is reported in the corrected version; *dw* is the Durbin-Watson statistic;  $Q(1)$  and  $Q(4)$  are the Box-Ljung statistics for one and four lags, respectively, with the associated p-values in parentheses.

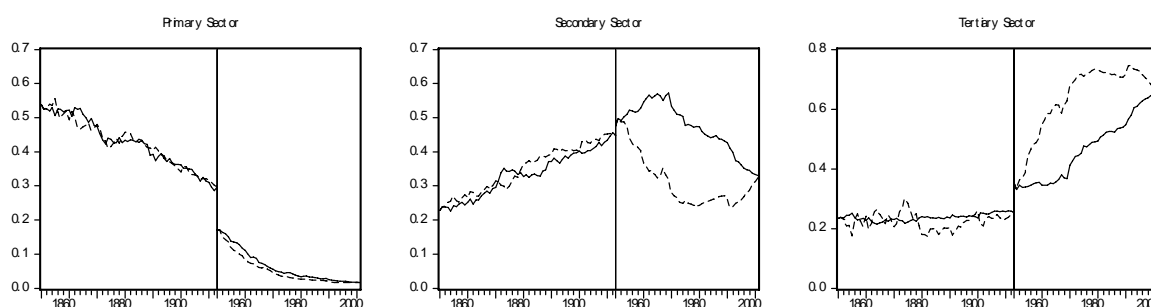
By contrast to the results for employment, the estimates of specification A2 show a significantly negative coefficient for the lagged dependent variable in the case of the primary sector. A significant structural break is present only in the secondary sector. With the



inclusion of the macroeconomic variables in specification B2 the autoregressive dependence weakens and loses significance in the secondary sector. The macroeconomic variables are, however, not significant in any case here. In specification C2 the linear trend with a possible break is added. This causes the dummy variable post1950 for a structural break in the intercept to be significant. In addition, there appears to be a structural break in the trend. The macroeconomic variables are here again insignificant. This appears to be a major difference to employment where GDP growth is significant and the structural break is less important. Concerning the explanatory power, the values of  $R^2$  here begin to rise not until the deterministic trend is introduced in specification C2. The  $Q$  statistics show that residual autocorrelation is absent in all specifications.

As for the employment shares, the following figures 4 to 6 plot the realized time paths of the value-added shares as the solid and the paths of the numerical solution as the dashed lines. Comparing the development of the employment and the value-added shares it becomes apparent that the general pattern is rather similar. Also in terms of value added the share of the primary sector declines, the share of the tertiary sector rises and the share of the secondary sector is inverse U-shaped. In parallel to specification A1 the fit of specification A2 is very good for the primary but considerable weaker for the other sectors (figure 4). The corresponding squared correlation coefficients are 0.994 for the primary, 0.089 for the secondary and 0.854 for the tertiary sector.<sup>6</sup> Thus, the fit for the secondary sector is much lower in the case of the value-added shares.

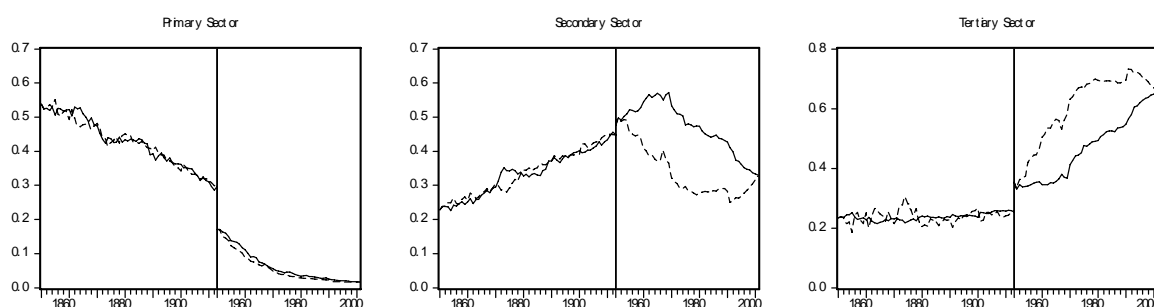
Figure 4  
Value Added Shares with Solution from Specification A2



As in the case of employment shares, the inclusion of the macro-variables improves the fit of the numerical solution to the realized development only slightly in the case of the secondary

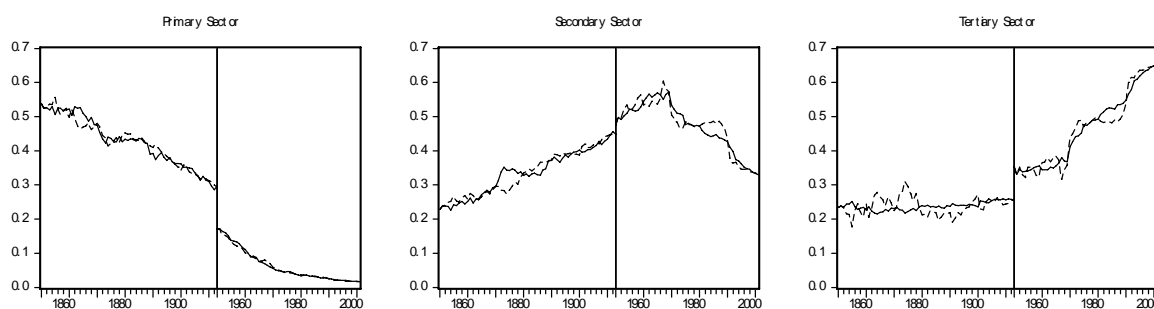
sector (figure 5). The goodness-of-fit measures are here 0.995, 0.303 and 0.891 for the primary, secondary and tertiary sectors, respectively. Nevertheless, it remains much lower for the secondary sector compared to the other sectors.

Figure 5  
Value Added Shares with Solution from Specification B2



This changes once the deterministic trend with a possible structural break is included in specification C2 (figure 6). Now the solution tracks the realized development quite well for all three sectors and is also able to fit the inverse U-shaped form of the time path of the secondary sector. The goodness-of-fit is here 0.994, 0.944 and 0.955 for the primary, secondary and tertiary sectors, respectively.

Figure 6  
Value Added Shares with Solution from Specification C2



In sum, the results show that analogously to the results of employment the pure autoregressive specification has some difficulties in replicating the sector shares. In contrast to employment the impact of the macroeconomic variables is only of minor importance whereas the inclusion

<sup>6</sup> The difference in the squared correlation coefficients of the secondary and the tertiary sector seems to appear a little bit puzzling at first, but becomes much more reasonable once a scatter plot of realized and fitted values is considered.

of the deterministic trend with a break is suitable to bring the numerical solution close to the realized development.<sup>7</sup>

## 6. Conclusion

The main result of this paper is that a simple model based on Fourastiéian ideas is quite capable of explaining the decline of the primary, the rise of the tertiary and the inverse U-shaped development of the secondary sectors in terms of shares in total employment or value added. Two constituting ideas featured by Fourastié (1949/69) are sectorally differing rates of demand growth as a consequence of the convergence towards sector-specific saturation levels with rising economy-wide income and employment flows across sectors due to productivity differences inducing wage dispersion. The model can be expressed in terms of growth rates of sectoral and economy-wide employment and value added. It is estimated as an equation system and evaluated by the fit of the numerically calculated shares of either employment or value added to their realized counterparts. Despite the reasonable fit in general, the model appears to be better suited for the case of the employment shares rather than for the case of the value-added shares. In the latter case the fit is almost entirely due to the introduction of a trend with a structural break instead of the macro-variables suggested by theory.

Of course, the theoretical model is very simple and does not explicitly consider the forces that lead to productivity improvements in the sectors. Moreover, the current version of the model does not account for direct sectoral interdependencies and feedback effects from the change of the sectoral composition to the macroeconomic outcomes. In our future work we plan to improve the theoretical underpinnings to address these weaknesses by searching for an explicit integration of the mechanism for structural change proposed here into a multi-sectoral model of endogenous economic growth. On the empirical side a more disaggregate analysis for the period after World War Two seems to be promising. This analysis aims at identifying those sectors or industries that shape the process of deindustrialization towards tertiarization in a particular way.

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<sup>7</sup> We also repeated the analysis of this section for the two alternative ways to construct the value-added series explained in appendix A which overall confirmed the reported findings.

## Appendix A: Sectoral Data

### Employment:

Employment is measured as the number of employed persons, including paid employees, self-employed persons and unpaid family workers. We have complete annual time series for 1878-1913 and 1950-2003. Incomplete data exist from 1850 until 1878 and between the two world wars.

1850-1939: Hoffmann (1965), table 19 (pp. 203f.) and table 20 (pp. 204f.)

1939-1944: Wagenführ (1963), table 2 (p.139) and table 3a (pp. 104ff.)

1950-1991: Groningen Growth and Development Centre (GGDC), 10-Sectoral Database, van Ark (1996)

1992-2003: Groningen Growth and Development Centre (GGDC), 60-Industry Database, O'Mahony and van Ark (2003)

### Net Value Added:

Valued added is defined as real net value added at factor costs (gross value added minus depreciations minus indirect taxes plus subsidies). Complete time series for value added are available from 1850-1939 except for the period 1914-1924. For the period since 1950 we use data from the national accounts of the German federal statistical office (Statistisches Bundesamt).

1850-1939: Hoffmann (1965), table 100 (p. 450) and table 103 (pp. 454f.)

1950-1957: Statistisches Bundesamt (1960): Statistisches Jahrbuch 1960, table 3 (pp. 543f.)

1958-1959: Statistisches Bundesamt (1962): Statistisches Jahrbuch 1962, table 4 (pp. 565f.)

1960-1966: Statistisches Bundesamt (1971): Statistisches Jahrbuch 1971, table 4 (pp. 505f.), with 1962 from Statistisches Bundesamt (1967): Statistisches Jahrbuch 1967, table 4 (pp. 521f.)

1967-1969: Statistisches Bundesamt (1974): Statistisches Jahrbuch 1974, table 4 (pp. 509f.)

1970-2003: StasisBund Online (<http://www.destatis.de/genesis>), corrected for public services with data from Statistisches Bundesamt, Fachserie 18, Reihe 1.4, tables 3.2.1 and 3.4.3.1

Concerning *net* value added, mining and energy generation are treated as a single industry in the official statistics during 1950-1969. To allocate mining to the primary and energy

generation to the secondary sector we assigned depreciation, indirect taxes and subsidies to mining and energy generation according to their shares in *gross* value added. The accuracy of this operation depends on the relation of net and gross value added in both industries. Required additional data are taken from:

- 1950-1957: Statistisches Bundesamt (1960): Statistisches Jahrbuch 1960, table 4 (p. 545)
- 1958-1959: Statistisches Bundesamt (1962): Statistisches Jahrbuch 1962, table 5 (p. 567)
- 1960-1961: Statistisches Bundesamt (1964): Statistisches Jahrbuch 1964, table 5 (p. 551)
- 1962-1964: Statistisches Bundesamt (1967): Statistisches Jahrbuch 1967, table 5 (p. 523)
- 1965: Statistisches Bundesamt (1972): Statistisches Jahrbuch 1972, table 5 (p. 517)
- 1966-1969: Statistisches Bundesamt (1973): Statistisches Jahrbuch 1973, table 5 (p. 524).

This construction of the value-added series, however, suffers from the fact that we have available real net values added before 1950 due to the reliance on the Hoffmann source, but use net value added at current factor costs after 1950. To assure against the possible error committed with that choice we also computed the results for two alternative constructions of value added. The first alternative is to use the real gross value-added data from the 10-Sectoral Database of the GGDC in prices of 1985 for the years 1950-1991 and extend these data to the period 1992-2001 by suitably summarized and deflated data from the 60-Industry Database of the GGDC.<sup>8</sup> The second alternative is to take net value added of the year 1995 from the Statistisches Bundesamt and extend this to the whole period 1950-2001 by growth rates based on the real gross value-added data from the 10-Sectoral Database and the 60-Industry Database of the GGDC.

We did our best to harmonize the varying industry classifications used in these different data sources oriented at the ISIC classification. Anyway, possible inconsistencies should be of minor importance at this high level of aggregation. Because of the data availability we were forced to accept the current political borders for the respective time periods. For the period before 1871 the censuses of enterprises in 1846 and 1861 are taken as representative for the German Empire without Alsace-Lorraine. For the period 1918 to 1944 the German territory is assumed to exclude Austria and the Sudetenland, but comprising the Saarland since 1934. For the time period after World War Two, Germany is defined as West-Germany excluding the

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<sup>8</sup> For the industries 30 (office machinery) and 321 (electronic valves and tubes) the harmonized US deflators instead of the national deflators are used.

Saarland and West-Berlin until 1959, as West-Germany including the Saarland and West-Berlin from 1960-1991 and as unified Germany afterwards.

### **Appendix B: Unit-Root and Stationarity Test Results**

This appendix reports the results of our unit-root and stationarity tests for the variables used in the body of the paper. The specific tests applied are:

- the ERS point optimal test of the unit-root null hypothesis (Elliot et al. 1996)
- the KPSS test of the reverse stationary null hypothesis (Kwiatkowski et al. 1992) with critical values from Sephton (1995)
- the Perron test of the unit-root null hypothesis (Perron 1989) with an a priori assumed structural break fixed between the years 1913 and 1950 and critical values calculated by implementing the response-surface estimates of Silvestre et al. (1999)
- the Kurozumi test of the stationary null hypothesis (Kurozumi 2002) also with an a priori structural break fixed between the years 1913 and 1950
- the Zivot-Andrews test of the unit-root null hypothesis (Zivot and Andrews 1992) with an endogenously searched break date

In the subsequent tables the results of these five tests are reported for each of the three sectors (primary, secondary and tertiary) in terms of sectoral employment and value added, respectively, as well as the macroeconomic variables GDP, population and GDP per capita. Throughout, all variables are expressed in natural logarithms. Autocorrelation is controlled for up to a lag of three years in the test regressions and the window widths. To show the robustness of the findings, this is preferred to the determination of an optimal lag length by t-tests or information criteria. For all tests the variants with an intercept only and with both intercept and trend are computed.

The test outcomes for employment in table 3 give a clear indication of the existence of a unit root in all three sectors irrespective of the lag length chosen. The unit-root tests are not able to reject their unit-root null hypothesis, whereas the stationarity tests vividly reject their stationary null hypothesis. This holds for the ERS and KPSS tests without the permission of a structural break as well as for the Perron and Kurozumi tests with an a priori fixed break between 1913 and 1950 (the data gap described in the text). Somewhat conflicting results

come from the Zivot-Andrews test with an endogenously chosen break date. From this test we have a rejection of the unit-root null hypothesis for the tertiary sector when the deterministic component consists of an intercept only and for the primary sector in the case of both intercept and trend. In sum we interpret the whole set of results as evidence in favor of a unit root in sectoral employment and therefore use first differences of the logged variables in our regressions. This decision is also made in the light of the dangers of the spurious correlation problem in time series regression (Phillips 1986) which is deemed to be much more serious than the reverse problem of overdifferencing when residual autocorrelation is absent (Plosser and Schwert 1977). The results for employment without application of the logarithm appear to be quite similar.

For the case of value added table 4 the picture is rather similar. The only rejections from the Perron test are for cases without control for autocorrelation and are therefore somewhat suspect. The Zivot-Andrews test leads here to a more consistent rejection of the unit root for both the secondary and the tertiary sector.

In the case of the GDP and population series we have a clear-cut confirmation of a unit root in the case of the population time series as can be inferred from table 5. The rejections of the Zivot-Andrews test for GDP and GDP per capita are not very plausible in the light of the trending behavior of both series. This becomes evident once a linear trend with a possible break in that trend is considered. Now the Zivot-Andrews test is no longer able to reject the unit-root hypothesis, completely in line with the other four tests.

Table 3  
Unit-Root and Stationarity Tests for (log) Employment

	ERS	KPSS	Perron	Kurozumi	Zivot-Andrews
<u>Intercept:</u>					
P 0	1.470	8.473 ***	-2.451	2.817 ***	-3.694
P 1	1.300	4.292 ***	-2.316	1.498 ***	-3.709
P 2	1.144	2.891 ***	-2.052	1.031 ***	-3.722
P 3	1.027	2.190 ***	-1.962	0.793 ***	-3.715
S 0	0.036	6.514 ***	-1.920	1.292 ***	-2.835
S 1	-0.050	3.342 ***	-1.911	0.678 ***	-2.907
S 2	-0.096	2.274 ***	-2.234	0.476 ***	-2.975
S 3	-0.084	1.740 ***	-2.199	0.376 ***	-3.015
T 0	2.895	8.105 ***	-2.890	2.351 ***	-5.618 ***
T 1	2.432	4.152 ***	-1.831	1.227 ***	-5.685 ***
T 2	2.129	2.822 ***	-1.868	0.853 ***	-5.711 ***
T 3	1.988	2.156 ***	-2.051	0.667 ***	-5.638 ***
<u>Intercept and Trend:</u>					
P 0	-1.385	1.250 ***	-5.448 ***	0.310 ***	-7.838 ***
P 1	-1.371	0.652 ***	-3.613	0.212 ***	-7.565 ***
P 2	-1.363	0.449 ***	-2.931	0.166 ***	-7.274 ***
P 3	-1.337	0.348 ***	-2.577	0.139 ***	-6.933 ***
S 0	-0.853	1.750 ***	-4.192 *	0.259 ***	-3.138
S 1	-0.982	0.912 ***	-2.587	0.141 ***	-3.334
S 2	-1.031	0.629 ***	-2.745	0.102 ***	-3.450
S 3	-0.982	0.487 ***	-3.178	0.083 **	-3.422
T 0	-1.664	0.706 ***	-2.807	0.389 ***	-4.917 *
T 1	-1.814	0.377 ***	-1.900	0.215 ***	-4.784
T 2	-1.919	0.266 ***	-1.972	0.153 ***	-4.600
T 3	-1.916	0.211 **	-2.134	0.122 ***	-4.296

Note: P, S and T in the first column indicate the primary, secondary and tertiary sector, respectively; the figure behind indicates the number of lags used in the test regression or the window width; rejections on 1, 5 and 10 percent level are indicated by \*\*\*, \*\* and \*, respectively.



Table 4  
Unit-Root and Stationarity Tests for (log) Value Added

	ERS	KPSS	Perron	Kurozumi	Zivot-Andrews
<u>Intercept:</u>					
P 0	2.524	11.529 ***	-3.890 **	2.853 ***	-4.896 **
P 1	2.979	5.827 ***	-2.461	1.487 ***	-4.302
P 2	2.624	3.919 ***	-2.360	1.026 ***	-4.161
P 3	2.072	2.963 ***	-2.261	0.795 ***	-4.020
S 0	5.519	11.483 ***	-2.454	2.742 ***	-8.258 ***
S 1	2.437	5.797 ***	-2.732	1.448 ***	-7.494 ***
S 2	1.885	3.895 ***	-2.036	1.004 ***	-7.998 ***
S 3	1.241	2.943 ***	-2.077	0.780 ***	-8.111 ***
T 0	6.159	11.162 ***	-1.621	2.474 ***	-5.820 ***
T 1	3.427	5.639 ***	-1.734	1.304 ***	-5.973 ***
T 2	2.214	3.791 ***	-1.190	0.900 ***	-6.028 ***
T 3	1.883	2.866 ***	-1.268	0.697 ***	-6.697 ***
<u>Intercept and Trend:</u>					
P 0	-2.098	1.807 ***	-4.285 **	0.228 ***	-4.893 *
P 1	-1.547	0.960 ***	-2.620	0.137 ***	-3.597
P 2	-1.431	0.662 ***	-2.581	0.103 ***	-3.082
P 3	-1.423	0.510 ***	-2.603	0.086 **	-2.807
S 0	-0.777	2.059 ***	-2.404	0.440 ***	-5.233 **
S 1	-1.062	1.043 ***	-2.749	0.252 ***	-5.174 **
S 2	-1.087	0.704 ***	-1.974	0.182 ***	-5.122 **
S 3	-1.191	0.534 ***	-2.009	0.146 ***	-5.068 *
T 0	-0.385	2.676 ***	-4.362 **	0.402 ***	-6.760 ***
T 1	-0.560	1.355 ***	-3.108	0.258 ***	-6.649 ***
T 2	-0.744	0.913 ***	-2.645	0.194 ***	-6.515 ***
T 3	-0.767	0.692 ***	-2.420	0.159 ***	-6.163 ***

Note: P, S and T in the first column indicate the primary, secondary and tertiary sector, respectively; the figure behind indicates the number of lags used in the test regression or the window width; rejections on 1, 5 and 10 percent level are indicated by \*\*\*, \*\* and \*, respectively.

Table 5  
Unit-Root and Stationarity Tests for (log) Macro-Variables

	ERS	KPSS	Perron	Kurozumi	Zivot-Andrews
<u>Intercept:</u>					
GDP 0	6.444	11.633 ***	-2.985	2.947 ***	-6.972 ***
GDP 1	2.520	5.874 ***	-3.493 *	1.555 ***	-6.062 ***
GDP 2	1.731	3.947 ***	-2.849	1.081 ***	-5.985 ***
GDP 3	1.007	2.983 ***	-2.683	0.842 ***	-5.674 ***
POP 0	5.031	11.486 ***	-0.785	3.499 ***	-2.372
POP 1	1.260	5.799 ***	0.365	1.812 ***	-2.111
POP 2	0.658	3.896 ***	0.572	1.240 ***	-2.064
POP 3	0.149	2.943 ***	0.285	0.953 ***	-2.113
GDPPC 0	5.790	11.427 ***	-2.647	2.627 ***	-6.783 ***
GDPPC 1	2.734	5.770 ***	-2.485	1.390 ***	-6.058 ***
GDPPC 2	2.026	3.878 ***	-2.250	0.969 ***	-6.295 ***
GDPPC 3	1.307	2.930 ***	-1.970	0.757 ***	-6.091 ***
<u>Intercept and Trend:</u>					
GDP 0	-0.717	1.642 ***	-2.653	0.512 ***	-4.499
GDP 1	-0.913	0.833 ***	-3.381	0.285 ***	-4.433
GDP 2	-1.017	0.562 ***	-2.559	0.205 ***	-4.600
GDP 3	-1.192	0.426 ***	-2.497	0.164 ***	-4.578
POP 0	1.101	2.240 ***	-2.747	0.686 ***	-3.652
POP 1	-0.071	1.135 ***	-2.909	0.368 ***	-3.706
POP 2	-0.452	0.765 ***	-2.832	0.257 ***	-3.795
POP 3	-0.855	0.581 ***	-3.017	0.202 ***	-3.770
GDPPC 0	-0.705	2.119 ***	-2.674	0.461 ***	-3.953
GDPPC 1	-0.882	1.072 ***	-3.244	0.255 ***	-3.882
GDPPC 2	-0.968	0.722 ***	-2.629	0.183 ***	-3.934
GDPPC 3	-1.122	0.547 ***	-2.349	0.147 ***	-3.941

Note: GDP, POP and GDPPC in the first column indicate the GDP, population size and GDP per capita series, respectively; the figure behind indicates the number of lags used in the test regression or the window width; rejections on 1, 5 and 10 percent level are indicated by \*\*\*, \*\* and \*, respectively.

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