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Does growth cause structural change, or is it the other way round?: a dynamic panel data analyses for seven OECD countries

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Does Growth Cause Structural Change, or Is it the Other Way Round?

A Dynamic Panel Data Analysis for Seven OECD Countries

by

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May 2009

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Abstract

In economic development, structural change among the three main sectors of an economy accompanies with aggregate economic growth. Nevertheless the question whether economic growth causes structural change or change in the economic structure causes aggregate growth is still unanswered. To shed some more light on this issue, this study examines a Granger-causality test in a panel environment to determine the causality of economic growth and structural change measured either in terms of employment shares or in terms of real value added shares. Estimation and analysis with annual data of seven OECD countries covering the period from 1960-2004 show that the causality appears to be heterogeneous.

JEL classification: L16, O14, O57

keywords: structural change, economic growth, tertiarization, panel Granger-causality-test

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1 Introduction

The analysis of structural change in the context of development and aggregate economic growth has a very long tradition and can be traced back to the classical literature of economics (e.g. Turgot (1766) or Smith (1776)). Nevertheless this issue is still prevailing in economic research today as pointed out by Silva and Teixeira (2008). In their overall survey on the matter of structural change they show the history of this branch of research with its many different approaches and facets. Furthermore, Krüger (2008a) surveys the existing research literature on structural change at various levels of aggregation with a special focus on the relation to productivity.

In this paper, structural change is conceived in the framework provided by the three-sector-hypothesis. Economic growth is associated with the phenomenon of structural change of the three main sectors of the private economy. Research investigating this phenomenon intends to explain the stepwise dominance of the so-called primary (agriculture and mining), secondary (manufacturing and construction) and tertiary (private services) sectors measured either in terms of employment or in terms of output. The literature offers several early contributions for explaining this pattern (see Fisher (1939, 1952), Clark (1949), Fourastié (1949/69)[2] and Wolfe (1955)).

That there exists an interrelation between the two phenomena of economic growth and structural change measured either in terms of employment shares or in terms of output shares is widely accepted in economic theory. The particular channels, which relate the two phenomena, are in a very complex manner and the direction of causality (whether economic growth determines structural change or changes in economic structure influence growth) is still an open question. Nonetheless neoclassical growth theory as Solow (1956, 1957) as well as new growth theory (e.g. Lucas (1988), Romer (1986, 1990), Grossman and Helpman (1991) and Aghion and Howitt (1992)) widely disregards these relationships. In their view, the chief cause of economic growth is only technical progress and therefore gains in productivity. Sectoral composition is constant and therefore structural change does not occur. The demand side is assumed to be homothetic and widely ignored in these theoretical frameworks.

More recently it is also tried to integrate structural change into formal growth theory (see e.g. Echevarria (1997), Kongsamut et al. (2001), Foellmi and Zweimüller (2002), Meckl (2002),

[2] 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 me.

Ngai and Pissarides (2007) and Bonatti and Felice (2008)). But in these models the causal direction from aggregate economic growth to structural change or vice versa is simply assumed.

The aim of this paper is to investigate the interrelation between structural change and economic growth. On the one hand, economic growth leads to higher income per capita which results in a shifting structure of demand as Engel's law predicts. This implies that economic growth is causing structural change due to adjustments in the production process according to demand side changes and that a higher rate of economic growth increases the speed of structural change. On the other hand, changes in the structure of the economy also influence the aggregate economic growth due to sectoral differing productivity gains.

As appropriate measures of structural change indices are used that reflect the speed of changes measured either in terms of employment shares or in terms of real value added shares. Aggregate economic growth is represented by the growth rate of real GDP. For the empirical testing a Granger-causality test in a panel environment as implemented by Hurlin and Venet (2001) is applied to data of the seven OECD countries France, Germany, Italy, Japan, the Netherlands, the UK and the US.

The empirical results show that the investigated countries are heterogeneous. In the case of employment, causality for the direction from aggregate economic growth to structural change is given for the four largest economies Germany, Japan, the UK and the US. Japan and the US show furthermore a bi-directional relationship. When structural change is measured in terms of real value added these results are widely confirmed. But beside the four largest economies now also France and the Netherlands show significant results for the direction from aggregate economic growth to structural change. For the direction from structural change to aggregate economic growth beside Japan and the US here also Italy, Germany and the UK show significant results.

The plan of the paper is as follows: The following section 2 outlines theoretical considerations for the causal relationship between economic growth and structural change. The next section 3 presents the data and some considerations about the sectoral development of the investigated countries. Section 4 explains the possibilities of how the speed of structural change can be measured and derives the underlying test procedure to ascertain whether causality is present in this circumstance. Furthermore the estimation strategy is outlined and the results of an extensive testing for unit roots are summarized. The empirical results of the causality tests between economic growth and structural change in terms of employment and in

terms of real value added are discussed in section 5. The subsequent section 6 concludes with a summary of the main results and some implications.

2 Theoretical Considerations

Growth theory does not take into account structural changes of the three macro sectors of an economy and most papers trying to explain the patterns of structural change assume mainly that growth drives the changes in sectoral composition of an economy measured in terms of employment or in terms of output than the other way round. Pelka (2005) investigates theoretical models dealing with the topic of structural change and economic growth and finally finds out that only "the growth process promotes structural change" (Pelka (2005), p. 292; author's translation). Kongsamut et al. (2001) have shown that balanced-growth is possible consistent with massive changes in the sectoral composition. Meckl (2002) confirmed this view and this leads him finally to the assumption that "structural adjustment is only a by-product of economic growth that has no feedback on the growth process itself" (Meckl (2002), p. 264). This leads to the result, that aggregate economic growth is causing structural change (measured in terms of employment as well as in terms of real value added) but structural change (measured in terms of employment or in terms of real value added) is not causing aggregate economic growth.

In the literature of structural change theory it is the prevalent opinion that changes in the economic structure occurs in the light of two opposing components, preference changes of the demand and sectoral specific productivity gains (e.g. Fisher (1939, 1952), Fourastié (1949/69) and Pasinetti (1981)).

On the demand side, actors consume products and services of the three sectors according to their personal preferences and hence spend their income in a certain distribution for goods of the primary, secondary and tertiary sector, respectively. This distribution does not remain constant as income rises but changes as preferences change with increasing income. That means the structure of demand for products of the different sectors is varying with increasing income. As suggested by Engel's law, the share of basic needs as agricultural products decreases as income increases. Fourastié (1949/69) assumes on the demand side a hierarchy of needs that is associated with different saturation levels for the goods of the three sectors ("demand hypotheses"). 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. Corresponding empirical evidence for different

income elasticities among the products of the secondary and tertiary sectors are given for example by Curtis and Murthy (1998), Rowthorn and Ramaswami (1999) and Möller (2001). Those papers support these theoretical considerations of dissimilar income elasticities across the sectors. The income elasticity is found to be above unity for most of the service branches and for the whole service sector as aggregate. It is below unity for manufacturing branches as well as for the whole sector.

On the supply side the "productivity hypothesis" indicates that different technical progress in the sectors is decisive for structural change. That means, that caused by different levels of technical progress among the three sectors a shifting of the sector shares takes place in the light of the following intuition. Technical progress is an increase in technical knowledge which allows e.g. for a better production process. Therefore, labor productivity increases and less input of employment is needed to produce one item of output. This increase in labor productivity results via reduction of prices or via increases in wages or profits in a higher real wage on average. Hence the income and therefore the demand for goods of the three sectors can increase.

Theoretical models dealing with this topic assume either non-homothetic preferences as driving force for structural changes in the sectoral composition (e.g. Echevarria (1997), Kongsamut et al. (2001), Meckl (2002)) or assume that different productivity increases and their consequences are responsible for a changing economy (e.g. Baumol (1967), Krüger (2008b)).

Fourastié (1949/69) verbally states that the demand side is the driving force for the direction of structural change and Dietrich and Krüger (2008) provide empirical evidence based on a simple model demonstrating that this holds for the German economy.

Taken together, these considerations lead to the hypothesis that structural change is induced by economic growth. Higher growth rates of economy-wide GDP in one period should then lead via rising income and changing demand to more structural change or to a higher speed of structural change in the following period(s) measured either in terms of real value added shares or in terms of employment shares of the three main sectors.

Contrariwise one has also to take into account the possible effects of a changing structure in demand and corresponding changes in the structure of employment and hence real value added on aggregate growth. Changing behavior in consumption due to the fact of rising income as explained above leads to an adjustment process of supply in terms of labor input and real value added. This will then lead to an adjustment of the aggregate economic growth

rate depending on the productivity gains or losses which are accompanied with these changes. If demand increases faster in sectors with low or without productivity growth than in those sectors with high productivity growth the changes in the sectoral structure negatively affect aggregate economic growth. Following Baumol (1967) these negative feedback effects on economic growth happen in the process of tertiarization and are often also called Baumol's cost disease. More recent work confirming this view is provided e.g. by Baumol et al. (1985) or Nordhaus (2006). As a consequence of technical progress in one sector the labor set force in this sector can switch to another sector. Because of the increasing demand in the stagnant sector cannot be satisfied via technical progress higher labor input is needed. Appelbaum and Schettkat (1995) show that there exits a statistical significantly negative interrelation between employment and labor productivity. Following this argumentation a higher speed of structural change (measured in terms of employment shares as well as in terms of real value added shares) should slow down aggregate economic growth in the time path of tertiarization.

A negative impact of structural change on aggregate economic growth in this theoretical considerations are only due to the assumption that demand is increasing in stagnant sectors faster than in productive ones. This requires in the phase of tertiarization that services are less productive than manufacturing goods and agricultural goods. As pointed out, by far not all services today are stagnant. Services are more often used as intermediate goods and therefore have also important impact in the production process of manufacturing and agricultural goods. Grubel and Walker (1989) have shown that producer services which are of input nature entailing provision of innovative services to other firms in the economy. They grew rapidly and increased their share of GDP compared to other services. More recently this trend was confirmed by e.g. Fixler and Siegel (1999) or Oulton (2001).

Furthermore it might be the case that rigidities impede aggregate economic growth. Changes of the employment structure and the real value added structure are necessary due to changes in the demand structure. If higher productivity and higher output values do not stand in line with the appropriate levels of demand for the products the consequence is declining prices. This would then finally lead to a non efficient use of resources. As Aiginger (2001) points out his diagnosis of too slow structural change allowes for different policy conclusions. On the one hand it might be argued that prospective growth sectors have to be supported by government. One the other hand, and this is more important in the light of macroeconomic structural change, rigidities have to be eliminated to let structural change happens. Examples here are deregulation, privatization and reduction of wage and job rigidities. Following this argumentation, structural change should lead to a higher rate of aggregate economic growth.

Empirical work done so far does not investigate these linkages. Echevarria (1997) investigates the relations between the sectoral structure of an economy and aggregate economic growth. She shows a hump shaped relationship between the growth rate of GDP per capita and the sectoral composition. Less developed countries have the smallest growth rate of GDP per capita, followed by those countries with very high incomes. Countries with medium-high incomes have the largest growth rates. In her view, the sectoral composition plays a major role for the growth rate of GDP. On the contrary, in this paper we try to find out whether there is a linkage between the changes in sectoral composition and aggregate economic growth.

Stamer (1998, 1999) investigates the interrelation between subsidies, structural change and economic growth for West-Germany with sectoral data from 1970 until 1993 disaggregated to 41 industries by using the modified Lilien index. In his Granger causality analysis he finds quite strong evidence that growth has an impact on structural change as well as vice versa but with a stronger evidence that structural change is depending on aggregate economic growth than vice versa. With the aid of impulse response functions he found out that growth accelerates structural change and structural change slows down growth. Aiginger (2001) surveys the interrelation between economic dynamics and structural change of production by using the norm of absolute values as an index for structural change. He uses a disaggregation level of either 23 sectors (2-digits NACE) or 99 industries (3 digits NACE) with data from 1985 to 1998 for 14 European countries, the US and Japan. A simple time-lagged correlation test indicates that structural change has a deeper impact on growth as vice versa. Ansari (1992) empirically investigates the growth implications of structural change accompanying the tertiarization by the usage of Canadian data from 1961 to 1988. As indicators for structural change the development of the sector shares as well as the sector growth rates are used. This research found adverse growth implications of deindustrialization. All these papers used a more disaggregated classification than the three main sectors. In contrast to their work this paper divides the economy into the three main sectors of an economy and investiagtes 7 of the most developed countries.

3 Data and Descriptive Statistics

- *Data*

This investigation considers a panel of the seven OECD countries France, Germany, Italy, Japan, the Netherlands, the United Kingdom and the US with annual data from 1960 until 2004, where data availability is given for all included countries such that the panel is balanced.

Sectoral employment is measured as the number of employed persons (including paid employees, self-employed and unpaid family workers). Sectoral value added is measured in the home currency of the country deflated by the Laspeyres index. All sectoral data are taken from the Groningen Growth and Development Centre (GGDC, see van Ark (1996)) and from the EU KLEMS database (see Timmer et al. (2008)). The data for real GDP are taken from the Penn World Table (see Heston et al. (2006)) and are also deflated by the Laspeyres index.[3]

- *Descriptive Statistics*

a) Development of the Sector Shares

To find out similarities and differences between the countries concerning their development and to find out similarities and differences between sectoral employment or sectoral real value added, some descriptive statistics are investigated. Figures A3 and A4 in appendix 3 show the development of the shares of the three sectors for the seven investigated countries measured in employment and real value added, respectively. For the case of employment the share of the primary sector is monotonically declining over the whole time span for all countries. The secondary sector shares follow an inverse U-shaped curve and the share of the tertiary sector monotonically increases as time goes by. The speed of change and the shares in the initial period as well as in the last period are quite different as it is can be seen in the following table 1.

Table 1. Development of Employment Shares

	Share P		Share S		Share T		Maximum S	
	1960	2004	1960	2004	1960	2004	Year	Share
France	0.277	0.052	0.397	0.289	0.326	0.658	1973	0.445
Germany	0.190	0.032	0.491	0.340	0.318	0.628	1970	0.532
Italy	0.372	0.053	0.363	0.353	0.265	0.594	1980	0.455
Japan	0.370	0.063	0.318	0.315	0.312	0.622	1973	0.398
Netherlands	0.141	0.045	0.421	0.234	0.438	0.720	1965	0.436
UK	0.098	0.020	0.475	0.252	0.427	0.728	1969	0.487
USA	0.168	0.038	0.376	0.228	0.456	0.734	1966	0.388
average	0.231	0.043	0.406	0.287	0.363	0.669		0.449

Note: P, S and T are the primary, secondary and tertiary sectors, respectively.

While the primary sector is dominating the economy in the initial period for Italy, Japan and France, it has only a minor share for the UK, the Netherlands and the US. Germany has about one-fifth of its labor force engaged in the primary sector at this time which is only slightly

[3] For a detailed description of the dataset used please see appendix A1.

below average. In 2004 the shares declines to a level between slightly more than two percent for the UK and about six percent for Japan. All countries are very close together and the ranking of the countries is almost the same which means that those with a relatively high share in 1960 have a relatively high share in 2004 and vice versa but the distance between the countries became less, that convergence appears. Germany is an exception, its shares is on average in 1960 but the second smallest in 2004.

The secondary sector averages about 40 percent of the whole economy in 1960. It is the dominating sector for Germany and the United Kingdom with 49 and 47.5 percent, respectively. Nonetheless all observed countries are already highly industrialized at this time or the industrialization process is nearly finished as it can be seen in the last column of table 1 where the maximum share of the secondary sector and the corresponding year are shown. These maxima are only slightly above the shares of 1960, except for France which gains more than 11 percentage points. On average the economies reach more than 40 percent of their whole employment in the secondary sector. All economies reach their maximum values within the first half of the observation period and hence the investigated pattern can be assumed to be the pattern of tertiarization. Especially the Netherlands, the UK and Germany has a large decrease in their secondary sector shares with about 20 percentage points less in 2004 than in their maximum period. In 2004 the secondary sector was not dominating any longer any country.

The tertiary sector share increases monotonically for all countries and gains about 30 percentage points during the observation period such that on average two third of the working force are employed here in 2004. Beside, the level differences between the economies are largest in the shares of the tertiary sector. While it is dominating in the US and the Netherlands in 1960, Italy employs only 25 percent of its working force at the same time. As in the case of the primary sector, the ranking of the countries does not change over time and same signs of convergence can be found even though it is not as strong as in the case of the primary sector. The US, the UK and the Netherlands, which are the leading countries in 1960, are also leading in 2004. Their tertiary sector share is about 73 percent about 10 percentage points above and thus the shares of the follower countries France, Germany and Japan. Italy had still the lowest share with slightly below 60 percent.

The pattern of sectoral development measured in terms of real value added is considerable different from the sectoral development measured in employment as it can be seen in figure A4 in appendix 3. Overall the curves of the sector shares of the three sectors are flater and the

inverse U-shape of the secondary sector is not as distinctive as in the case of employment. This is also reflected in the differences between the maximum values of the secondary sector and the initial shares in 1960 as can be seen in table 2.

Table 2. Development of Real Value Added Shares

	Share P		Share S		Share T		Maximum S	
	1960	2004	1960	2004	1960	2004	Year	Share
France	0.438	0.041	0.211	0.297	0.351	0.662	1978	0.325
Germany	0.075	0.021	0.495	0.347	0.430	0.632	1970	0.522
Italy	0.074	0.045	0.369	0.326	0.557	0.629	1980	0.386
Japan	0.154	0.017	0.393	0.376	0.453	0.606	1976	0.438
Netherlands	0.054	0.064	0.343	0.274	0.603	0.662	1968	0.386
UK	0.094	0.038	0.438	0.288	0.468	0.674	1973	0.464
USA	0.063	0.050	0.461	0.301	0.476	0.649	1966	0.476
average	0.136	0.039	0.387	0.316	0.477	0.645		0.428

Note: P, S and T are the primary, secondary and tertiary sectors, respectively.

The typical pattern has been achieved only for Germany, the UK and the US and to some extend France. Altogether the characteristics of monotonically development of the sector shares cannot be ascertained in the case of real value added. In fact higher fluctuations in the development of the sector shares are apparent. Nonetheless the direction of development is the same as in the case of employment. The tertiary sector gains as time goes by whereas the primary sector looses. The secondary sector first increases and then decreases. A major exception is the case of the Netherlands. Here the primary and the secondary sector are inverse U-shaped in their pattern while the tertiary sector is U-shaped.

Altogether, the development pattern of the investigated countries are similar, even though the changes in the sectoral composition differ in their speed. More apparent are the differences in the investigated series (employment or real value added).

b) Development of the Sectors

The reasons for these differences might be diverse. It is often mentioned that structural change in terms of value added is caused by price differences and diminishes when using real terms. As figure A4 in appendix 3 shows, the changes are also present when measuring in terms of real value added. A second reason might be the differences in total sectoral development. Therefore table 3 shows the growth factors[4] of the sectoral employment and the sectoral real value added, respectively.

[4] The growth factor equals the growth rate plus unity. A very fortune feature of this measure is that it reflects the share of employment or real value added in 2004 of the starting value in 1960.

Table 3. Growth Factor 1960-2004

	Employment				Real Value Added			
	P	S	T	tot	P	S	T	tot
France	0.206	0.798	2.209	1.094	0.247	3.727	5.013	2.655
Germany	0.177	0.721	2.056	1.043	0.886	2.237	4.680	3.186
Italy	0.152	1.036	2.395	1.068	2.438	3.580	4.581	4.052
Japan	0.223	1.291	2.597	1.303	2.003	17.039	23.786	17.776
Netherlands	0.494	0.859	2.538	1.542	5.022	3.389	4.644	4.235
UK	0.214	0.547	1.757	1.031	1.098	1.787	3.922	2.722
USA	0.666	1.182	2.798	1.952	3.425	2.800	5.835	4.285
average	0.304	0.919	2.336	1.290	2.160	4.937	7.494	5.559

Note: P, S and T are the primary, secondary and tertiary sectors, respectively.

First one can see that the overall working force increases only very slightly compared with the increases in overall real value added. For the UK, Germany, Italy and France employment grow less than ten percent during the whole observation period. Japan, the Netherlands and the US had larger increments with 30.3, 54.2 and 95.2 percent, respectively. Therefore shifts in the structure of employment are pure reallocations in the case of the former four countries while it might be also due to growth of overall employment growth in the latter three economies. The total growth factor of real value added is much higher for all countries compared to their growth factor of employment. But the increments are also much more dispersed. The range is between 2.66 for France and 17.78 for Japan.

The number of employees in the primary sector declined for all observed countries during the observation period and averaged in 2004 30.44 percent of labor of 1960. That means that the decline measured as share of the whole economy is accompanied by a decline of the working force in the primary sector in absolute numbers. For the case of real value added the absolute real value added of the primary sector declines only in France and in Germany. Only in these two countries the reallocation of employment goes along with a reallocation of real value added. In all other cases the real value added of the primary sector increases during the observation period even if varying a lot. While the UK gains only ten percent more real value added in 2004 compared to 1960 the Netherlands quintuples it at the same time.

In case of the secondary sector employment input decreased only for the UK, Germany, France and the Netherlands while it increased for Japan, the US and Italy. Real value added of the secondary sector increased for all countries even though large differences in the growth factors arise. While the UK amounts in 2004 1.79 times the amount of 1960 Japan realizes 17.04 times the amount in 2004 compared to 1960.

All countries exhibit a higher number of employment in 2004 than in 1960 in the tertiary sector. The growth factor averages 2.34 and lies between 1.76 for the UK and 2.8 for the US. At the same time the growth factor of real value added averages 7.49 and lies between 3.92 for the UK and 23.79 for Japan. Hence also the labor productivity of the tertiary sector increases even though these increases are not as high as in the primary and secondary sectors.

The investigation of these descriptive statistics showed that despite all differences in the levels of the sector shares across the seven countries the path of structural change is quite similar. This is more noticeable in the case of employment as in the case of real value added. Nonetheless these data allow the conclusion that structural change of value added is also present if real values are taken. Hence structural change cannot be assumed to be only an effect of prices. But these differences between the development of employment shares and real value added shares might deliver different results for the causality analysis. Hence it is important to investigate both of them.

4 Methodology

- *Measurement of Structural Change*

In the literature there are several possibilities to describe changes of the sectoral structure of an economy statistically. Concerning the three-sector-hypothesis usually the shares of the three main sectors are described in order to make some statements about the development of an economy. The main focus of attention is on the sector which is assumed to be the driving force at a particular stage of development. When industrialization is of interest the development of the secondary sector share is focused on and when tertiarization is of interest the share of the tertiary sector is observed more intensively in its progress. Since the aim of this paper is the detection of a general interrelation between economic growth and structural change, this approach seems not to be adequate. Therefore here it is summarized the changes of the sectoral composition of an economy between two points in time with the aid of a structural change index (SCI). The literature offers several indicators which might be applicable.

In this paper two different indices are used. The first is the most famous and probably also simplest index for measuring structural change, the Norm of Absolute Values (NAV) which is sometimes also called Michaely-Index (Michaely (1962)) or Stoikov-Index (Stoikov (1966)).

(1) $$NAV_{s,t} = 0.5 \cdot \sum_{i=1}^{n} \left| x_{[it]} - x_{[is]} \right|$$

For its computation first the differences of the sector shares x_i between two points in time s and t are calculated. Then the absolute amounts of these differences are summed up. Because all changes are counted twice by using this technique standardization is usually done by a division by two (e.g. Schiavo-Campo (1978)). This leads to a range of the NAV between zero and unity and therefore also the interpretation of the NAV is very easy. The amount of structural change equals exactly the share of the movements of the sectors as a percentage of the whole economy. If the structure remains unchanged the indicator is equal to zero and if all sectors change at its most, which means the whole economy has a total change then the index is equal to unity. This index is most frequently used in the German literature and therefore provides most comparability to other studies.

A second measure used in this paper is the modified Lilien index (MLI). It is derived from an axiomatic analysis of structural change indices. Krengel and Filip (1981) postulate that an indicator measuring the speed of structural change has to fulfil the characteristics of a metric. This leads to the following conditions for a SCI with x_{it} as the share of sector i at time t.

(C1) The index has to be equal to zero if the sectoral composition is unchanged:

$$SCI_{[s,t]} = 0 \Leftrightarrow x_{i_s} = x_{i_t} \forall i \in \{1,...,n\}.$$

(C2) Structural change between to points in time must be independent of the direction and only the extent of change is regarded (symmetry). That means, that the SCI only depends on the amount of changes and it is the same regardless whether it is measured from s to t or from t to s:

$$SCI_{[s,t]} = SCI_{[t,s]}.$$

(C3) Structural change of one period in time has not to be greater than the sum of the calculated structural change of at least two sub periods (triangle inequality).

$$S_{[s,t]} \leq S_{[s,q]} + S_{[q,t]} \text{ for } s < q < t.$$

Stamer (1999) deduces two additional requirements that shall be fulfilled by a SCI:

(C4) The index shall be a dispersion measure.

(C5) The index shall consider the weight (size) of the sectors.

The NAV fulfils all conditions except condition C4 that means the NAV is no dispersion measure but a metric. An often mentioned disadvantage of the NAV is that huge movements of a few sectors have the same impact on the index value as fewer changes of many sectors

and therefore are underestimated. But because in this paper only three sectors are considered, this problem is only of minor importance. Nonetheless, a second measure that fulfils all conditions shall be used for comparison.

A very prominent measure of structural change in the research field of structural unemployment is the Lilien-index (Lilien (1982)). For measuring the structural change in the demand for employment, Lilien developed an index that measures the standard deviation of the sectoral growth rates of employment from period *s* to period *t*. A weighting is done by the shares of employment in the recent period *t*.

(2) $$LI_{s,t} = \sqrt{\sum_{i=1}^{n} x_{[it]} \cdot \left(\ln \frac{x_{[it]}}{x_{[is]}} \right)^2}, x_{[is]} > 0, x_{[it]} > 0$$

Built on the axioms mentioned above, Stamer shows that the Lilien-index violates conditions C2 and C3. Furthermore he shows that a little modification is sufficient to solve this flaw and constructs a SCI that fulfills all required conditions. Therefore he modified the Lilien-index by augmenting it with the weighting by the shares of the sectors in both periods. Hence the influence of sector *i* is growing in proportion to its size on the one hand and to the value of his relative growth on the other hand. This index is constructed as:

(3) $$MLI_{s,t} = \sqrt{\sum_{i=1}^{n} x_{[is]} \cdot x_{[it]} \cdot \left(\ln \frac{x_{[it]}}{x_{[is]}} \right)^2}, x_{[is]} > 0, x_{[it]} > 0$$

The consideration of two measures for structural change has two main advantages. First it can be obviated that the choice of the SCI is the only reason of the observed relationships. Second the choice of these two special indices allows for a comparison of the results to other work that has been done in the German as well as in the Anglo-Saxon literature.[5]

- *A Test for Granger Causality in a Panel Framework*

The concept of Granger-causality goes back to Granger (1969) and is widely used to study causal effects between time series variables. The idea is that a cause cannot come after an effect, which means that the past can only predict the future but not vice versa. Therefore the causal relationship between two variables (bivariate case) can be determined by examining the way they move with respect to each other over time. In that sense a process X_t is said to

[5] Results not reported in this paper are computations with the usage of the Moore's test (Moor (1978)) and the Euclidean Norm (Schatz (1974)). These indices are also highly correlated with the two indices presented in the paper and yielded to very similar results in the analysis. Furthermore Driver and Saw (1996) have shown by the help of real data as well as simulated data that the structural change indices NAV and LI are highly correlated.

Granger-cause another process Y_t if future values of Y_t can be predicted better using past values of X_t and Y_t than using the past of Y_t only.

Of course this concept is not free of any criticism. Granger-causality does not imply true causality because it is only a necessary but not a sufficient condition for causality. So the post hoc ergo propter hoc fallacy is possible. The concept of Granger causality is only a weak concept and is telling merely about predictability than causality. Despite its imperfection the concept of Granger-causality is a standard tool for evaluating the character of the causal relationship between two variables and in this investigation the test of predictability is absolutely sufficient.

Recently, econometricians modified these Granger-causality tests to incorporate panel data. As pointed out in Hurlin and Venet (2001), the introduction of a panel data dimension allows using both cross-sectional and time-series information to test the causal relationships between two variables. A major advantage is the larger number of observations in this framework which increases the degrees of freedom and reduces the collinearity among the explanatory variables. Therefore the efficiency of Granger-causality tests can be improved notably. Besides, panel data allow for considerably more flexibility in the modeling of the behavior of cross-sectional units than conventional time series analysis (Greene (2008)).

When the Granger causality test is applied in the panel data framework two important inferential issues arise, both concerning the potential heterogeneity of the individual cross-sections. The first potential type of cross-section variation is due to distinctive intercepts, and this type of variation is addressed with a fixed effects approach. The other more problematic type of heterogeneity (causal variation across units) requires a more complex analytical response. Until recently, this type of heterogeneity was ignored (with unknown results).

Today there are diverse methods for causality tests in panel data models available. Erdil and Yetkiner (2005) classify mainly two types of approaches. The first one is pioneered by Holtz-Eakin et al. (1985) which lets the autoregressive coefficients as well as the coefficients slopes be variable across cross section units. This method is applied in a similar way by Holtz-Eakin et al. (1985), Hsiao (1986), Weinhold (1996), Weinhold (1999), Nair-Reichart and Weinold (2001), and Choe (2003). This type of literature largely ignores the second type of heterogeneity. The second approach treats the autoregressive coefficients and the regression coefficients as constant. This approach is used by Hurlin and Venet (2001), Hurlin (2004a), Hurlin (2004b) and Hansen and Rand (2004). This strain of literature explicitly addresses the latter type of heterogeneity and is therefore used in this paper. In their 2001 paper Hurlin and

Venet distinguish four kinds of possible causal relationships, homogenous non-causality, homogenous causality, heterogeneous non-causality and heterogeneous causality.

The econometric framework considers two covariance stationary variables x and y, observed for T periods and N individuals. For each individual $i \in I, N$ $x_{i,t}$ is said to Granger cause $y_{i,t}$ if past values of $x_{i,t}$ have a significant impact on $y_{i,t}$.

Following Hurlin and Venet (2001) the most general panel data solution is to test the causality from the variable x observed for individual i to the variable y observed for individual j, with $i = j$ or $i \neq j$. The second solution suggests testing causal relationships only for a given individual. This solution is more restrictive and cross sectional information is only used to improve the power of the tests. Hurlin and Venet note that in practice it is impossible to use completely optimal predictors and therefore they use only linear ones. Hence a time-stationary VAR representation is considered, adapted to a panel data context. They propose a model with fixed coefficients in the following style:

For each individual i, $\forall t = 1, ..., T$:

(4) $$y_{i,t} = \sum_{k=1}^{p} \gamma^{(k)} y_{i,t-k} + \sum_{k=0}^{p} \beta_i^{(k)} x_{i,t-k} + v_{i,t}$$

with $v_{i,t} = \alpha_i + \varepsilon_{i,t}$, where $\varepsilon_{i,t}$ are i.i.d.$(0, \sigma_\varepsilon^2)$ and the individual effects α_i are assumed to be constant. Furthermore they make two main distinctions to the work mentioned above belonging to the first type of approaches e.g. applied by Nair-Reichert and Weinhold (2001):

1. the autoregressive coefficients $\gamma^{(k)}$ are assumed to be constant for all k=1,...,p and
2. the regression coefficients $\beta_i^{(k)}$ are assumed to be constant for all k=1,...,p.

Additionally they assume that

3. the parameters $\gamma^{(k)}$ are identical for all individuals and
4. the regression coefficient slopes $\beta_i^{(k)}$ can have an individual dimension.

With these parameter settings both types of heterogeneity are controlled for. Individual intercepts α_i avoid the problem of potentially biased slope estimates which might lead to wrong inference in causality tests. The second, more crucial type of possible heterogeneity is related to the parameters $\beta_i^{(k)}$. As Pesaran and Smith (1995) point out, estimates under the wrong assumption $\beta_i = \beta_j \ \forall (i, j)$ are biased. Imposing the homogeneity of $\beta_i^{(k)}$ can then lead

also to wrong inference according to causality. It is possible that the causal relationship exists only for a subgroup of the whole sample. If the heterogeneity is ignored in this case probably the test represents only the outcome for the larger subgroup of the sample. To avoid this loss of power problem a nested test procedure has been imposed by Hurlin and Venet (2001) with the following main steps:

a) Homogenous non causality (HNC) hypothesis

This hypothesis implies that there is no causal relationship for all individuals. Therefore the slope coefficients associated with $x_{i,t}$ are tested to be zero for all individuals i and all lags k. The corresponding hypothesis test is defined as:

(5) $$H_o : \beta_i^{(k)} = 0 \;\; \forall i = 1,..., N, \forall k = 1,..., p$$

$$H_1 : \exists (i,k) / \beta_i^{(k)} \neq 0$$

To test these $N\,p$ linear restrictions the following Wald statistic is computed:

(6) $$F_{hnc} = \frac{(RSS_2 - RSS_1)/(Np)}{RSS_1 / [NT - N(1+p) - p]}$$

RSS_1 represents the sum of squared residuals of model (4) and RSS_2 denotes the sum of squared residuals of the restricted model. If the realization of this statistic is not significant, the HNC hypothesis is accepted which means that variable x is not causing y in all cross section units. If this is the case, the test procedure stops at this step. If the HNC hypothesis can be rejected, the homogeneity of the sample has to be investigated.

b) Homogenous causality (HC) hypothesis

The HC hypothesis is accepted if all the coefficients $\beta_i^{(k)}$ are identical for all lags k and are different from zero. Formally the H_0 is the following:

(7) $$H_o : \forall k = 1,..., p \;\; / \beta_i^k = \beta^k \;\; \forall i = 1,..., N$$

$$H_1 : \exists k \in [1, p], \exists\, (i, j) \in [1, N] / \beta_i^k \neq \beta_j^k$$

The corresponding Wald test is

(8) $$F_{hc} = \frac{(RSS_3 - RSS_1) / p(N-1)}{RSS_1 / [NT - N(1+p) - p]}$$

where RSS_3 corresponds to the sum of squared residuals of the restricted model where one imposes the homogeneity for each lag k of the coefficients associated to the variable $x_{i,t-k}$. If

this Wald statistic is not significant the conclusion would be that variable x is causing variable y in the N cross sections in a totally homogenous manner. If the HC hypothesis can be rejected this does not imply that there is no causal relationship at all, it only implies that the process is non homogenous and that no homogenous causality can be found. Hence a next necessary step is the heterogeneous non causality test.

c) Heterogeneous non causality (HENC) hypothesis

This test assumes that the non-existence of a homogenous causal relationship between two variables does not imply per se that there is no causal relationship at all. It might be the case that there exists such a relationship for at least one individual. Thus the third step in the testing procedure is to test for causality for each individual of the panel.

(9) $$H_o : \exists i \in [1, N] \,/\, \forall k \in [1, p]\ \beta_i^k = 0$$

$$H_1 : \forall i = 1,\ldots, N, \exists k \in [1, N] \,/\, \beta_i^k \neq 0$$

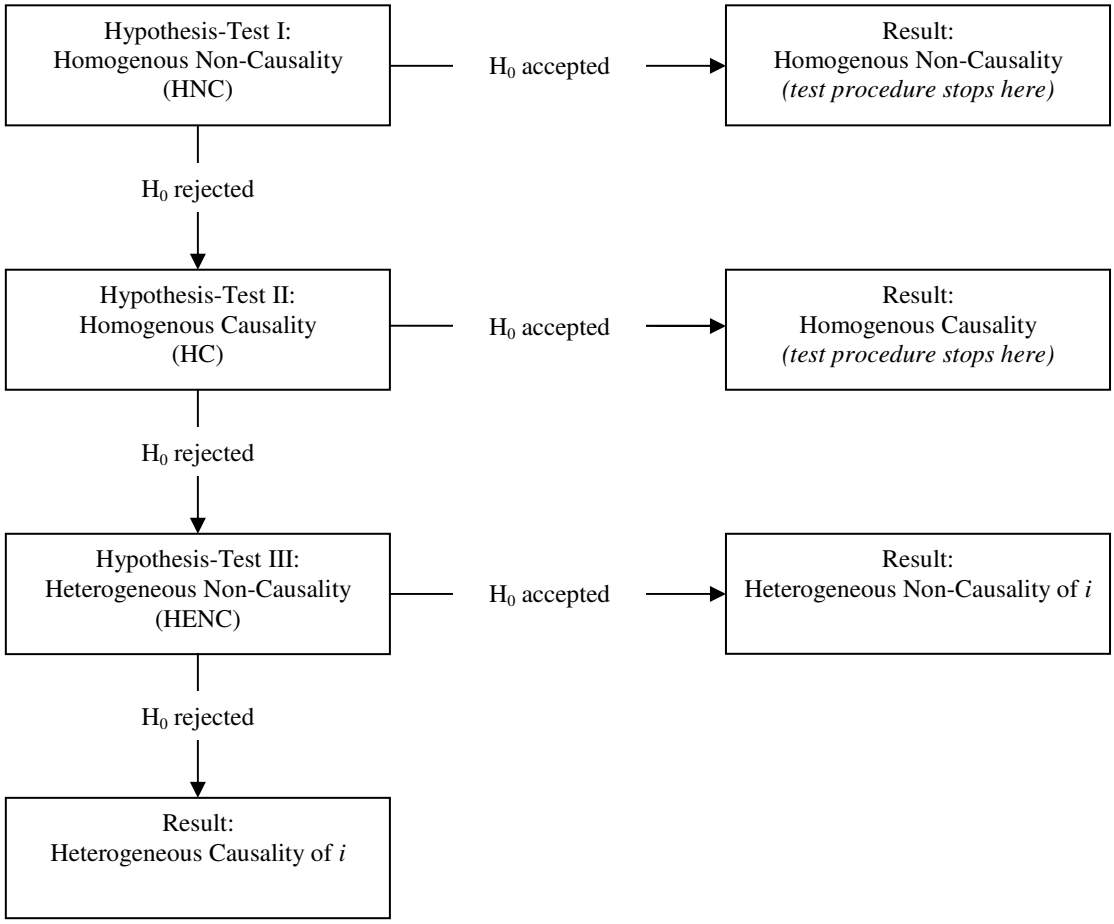
The corresponding Wald test is

(10) $$F_{henc}^{i} = \frac{(RSS_{2,i} - RSS_1) / p}{RSS_1 / [NT - N(1+2p) + p]}$$

where $RSS_{2,i}$ corresponds to the realization of the residual sum of squared obtained in model (4) when one imposes the nullity of the k coefficients associated to the variable $x_{i,t-k}$ only for individual i. A significant outcome indicates that x Granger causes y for individual i of the panel. If the F_{henc}^{i} test statistic is not significant the HENC hypothesis cannot be rejected for individual i which implies that there does not exist a causality relationship between x and y for this panel unit.

However, if suggested by theory, grouping of the panel units is possible and another HENC test can be done. In this case, the slope coefficients of a subgroup are tested against the null hypothesis of being zero. Furthermore one can test the HNC hypothesis and the HC hypothesis group wise to gain deeper insights into the structure of the causality between the two variables. To illustrate this nested test procedure once again it is summarized in the following figure 1.

Figure 1. Test Procedure for a Panel Granger Causality Test



Source: Illustration based on Hurlin and Venet (2001)

- *Estimation Strategy*

Since the validity of the statistical estimates depends on stationarity of the data series used we have extensively tested for unit roots. Detailed tables of the results as well as some graphs are shown in appendix 2 and are just summarized here for brevity. All panel unit root tests (Levin, Lin and Chu (2002) and Breitung (2000) for common unit roots and Im, Peseran, Shin (2003), Fisher-type test using ADF test (Maddala and Wu (1999)) and Fisher-type test using PP test (Choi (2001))) are able to reject the null hypothesis for a unit-root in all investigated series. The time series unit-root test (ERS point optimal test of the unit-root null hypothesis (Elliot et al. (1996))) is also able to reject the null-hypothesis of containing a unit-root in most of the cases. In ambiguous cases additional the visual inspection of the time series graphs gave additional certainty. Thus, all variables used for the estimates, the growth rates of economic-wide real GDP as well as the MLI and the NAV of employment shares and real value added shares, respectively can be taken as stationary.

The equations of the Granger causality tests are estimated with a fixed effects (FE) estimator. In this macro environment this seems to be more appropriate than a random effects (RE) estimator because if the individual effects represent omitted variables, it is very likely that these country-specific characteristics are correlated with the other regressors as argued by Judson and Owen (1999). The standard errors are corrected by using Period Seemingly Unrelated Regressions (PSUR) Panel Corrected Standard Errors (PCSE). This corrects for both period heteroskedasticity and general correlation of observations within a given cross-section as Beck and Katz (1995) point out.

The causality tests between economic growth and structural change are implemented over the whole time span from 1960 until 2004 with a lag order of one, two and three, respectively. The indices for structural change are measured with the MLI and the NAV for both, employment shares and real value added shares.

The application of a FE estimator in a dynamic panel data model asks the question of the influence of the dynamic panel bias. As is well known, the estimates of the FE estimator for the lagged endogenous regressors are biased and inconsistent and the bias changes with the inclusion of exogenous regressors (see Nickell (1981)). In the latter case the estimation for the exogenous variables is also biased when T is small.

Using consistent estimators as the GMM estimators derived by Arrelano and Bond (1991), Ahn and Schmidt (1995) or Blundell and Bond (1998) to correct for the bias are not suitable in this case because their properties are derived for a large cross-section dimension with a finite time dimension. It cannot be assumed that these properties hold with such a small cross-sectional dimension of 7 as it is present in this paper. Furthermore the trade-off between efficiency and the average bias of these estimators is a problem (Judson and Owen (1999)). Another solution might be to use of instrument variables (IV) estimators as the Anderson and Hsiao (1982) or bias corrected FE estimators as implemented by Kiviet (1995). But as mentioned by e.g. Beck and Katz (2004) these are not performing better than the simple methods per se and the costs of application are very high. Furthermore with these estimators the inclusion of more than one lag of the endogenous variable is not possible.

Nickell (1981) has shown also that the bias approaches zero when T approaches infinity, but the question remains when the time dimension can be regarded as large enough that the dynamic panel data bias can be neglected. Judson and Owen (1999) showed in a Monte Carlo simulation that the bias remains substantial when T equals 20. Even with a time dimension of 30 the bias can range from three up to 20 percent of the true value even if these errors would

still result in an estimate with the correct sign. Moreover the bias of the exogenous variables is very small. They suggest that the bias correction method is the best solution but this is not always practical to implement. For reasons already stated this estimation method cannot be used in this paper. For the case of *T* larger than the LSDV estimator performs just as well or better than the viable alternatives (GMM and IV). For these reasons in this paper where the time dimension is larger than 40 the LSDV estimator is applied. This is also supported by Hurlin and Venet (2001) who assumed that a time dimension of 31 is sufficient to consider the dynamic panel bias as negligible. They additionally argue that these results are unlikely to be sensitive to different estimators as the GMM and Anderson and Hsiao estimator.

As already mentioned, three specifications of the Granger-causality test with one, two and three lags included, respectively are done. This seems to be more appropriate than using an information criterion in this macro environment. The inclusion of the second and the third lag are first of all used to check for the robustness of the findings. Furthermore, they are used to find some relations that are not in the very short run.

5 Results

- *Results for Employment*

Table 4 shows the results of the homogenous non-causality hypothesis (HNC) for the case of employment and the two indicators of structural change. The left hand side of the table shows the results computed with the modified Lilien index (MLI) and the right hand side displays the results computed with the norm of absolute values (NAV). As can be seen in the table all results are very similar for both structural change indices.

Table 4. Test Results for Homogenous Non-Causality Hypothesis

	Modified Lilien-Index (MLI)		Norm of Absolute Values (NAV)	
Lags	Growth → SC	SC → Growth	Growth → SC	SC → Growth
1	2.9757 ***	1.5866	2.8347 ***	1.6008
2	5.4991 ***	10.1872 ***	4.4529 ***	8.4270 ***
3	5.7797 ***	10.6072 ***	4.3639 ***	10.5587 ***

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

The HNC that growth does not cause structural change is rejected strongly irrespective of the number of lags that are included. For the other way round the null hypothesis cannot be rejected for one lag. This indicates that aggregate economic growth causes structural change in the very short run but not the other way round. With the inclusion of a second and a third

lag, the HNC is rejected strongly also for the latter direction from structural change to aggregate economic growth. Then a bi-directional causality seems to appear.

After rejecting the HNC hypothesis, the next step is to test whether the causality is homogenous. Following the test procedure it has to be investigated whether all coefficients of the exogenous variable are identical for all countries of the panel which imposes strict homogeneity of the relationship between the variables in a next step. The results of the homogenous causality (HC) hypothesis are presented in table 5.

Table 5. Test Results for Homogenous Causality Hypothesis

	Modified Lilien-Index (MLI)		Norm of Absolute Values (NAV)	
Lags	Growth → SC	SC → Growth	Growth → SC	SC → Growth
1	3.3348 ***	0.4757	3.2528 ***	0.5745
2	3.9940 ***	3.5601 ***	3.3900 ***	3.3409 ***
3	4.4312 ***	6.5694 ***	3.4182 ***	6.9176 ***

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

Evidently, the basic pattern of significance is the same as before. For the causal direction from economic growth to structural change this hypothesis is strongly rejected no matter if the lag length chosen is one, two or three. When the causal direction is inverted, the HC hypothesis can be only rejected strongly for two and three lags. For one lag the HC hypothesis cannot be rejected, which is not overly surprising in the light of the previous result that the HNC is accepted and the coefficients have to be assumed to be zero. These findings imply that the panel is heterogeneous and that it is necessary to have a deeper look at the individual country level. Table 6 presents the results for the heterogeneous non-causality (HENC) hypothesis.

Table 6. Test Results for Heterogenous Non-Causality Hypothesis

		Modified Lilien-Index (MLI)		Norm of Absolute Values (NAV)	
	Lags	Growth → SC	SC → Growth	Growth → SC	SC → Growth
France	1	0.0746	1.5655	0.0608	1.7397
	2	0.8498	0.9660	0.9252	1.0013
	3	0.9478	0.6391	1.1269	0.5596
Germany	1	4.9201 **	1.2394	4.2773 **	1.0844
	2	17.0789 ***	0.5423	10.2783 ***	0.5424
	3	16.1166 ***	0.7823	11.5048 ***	0.6602
Italy	1	1.2917	0.0378	1.3836	0.0020
	2	2.0909	1.0155	2.8910 *	0.7225
	3	1.0714	1.5432	1.4784	1.3995
Japan	1	4.7971 **	1.0132	5.7151 **	1.2248
	2	3.5416 **	40.0022 ***	3.4382 **	34.1904 ***
	3	3.1454 **	52.7599 ***	2.6866 **	50.6291 ***
Nether-lands	1	0.0627	0.0018	0.0161	0.0042
	2	1.6390	0.5758	1.5911	0.5012
	3	1.5570	0.4851	1.4377	0.6929
UK	1	5.8036 **	2.6049	4.9299 **	2.5476
	2	5.0477 ***	1.5768	4.5676 **	1.5785
	3	6.3802 ***	1.4565	4.1712 ***	1.1719
US	1	5.4336 **	5.8210 **	4.7533 **	5.6824 **
	2	5.5018 ***	17.5358 ***	5.1374 ***	12.5365 ***
	3	6.1427 ***	14.1732 ***	4.9397 ***	11.6369 ***

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

Four out of the seven countries show strong support of the causality from growth to structural change. For Germany and the United Kingdom these findings are unidirectional whereas Japan and the US show also a causal link from structural change to growth. For the remaining countries France, Italy and the Netherlands the test statistics are never exceed their critical values and therefore structural change neither causes growth nor vice versa. To check these results the HNC hypothesis has been tested for the subgroup of France, Italy and the Netherlands. These results can be found in table 7.

Table 7. Test Results for Homogenous Non-Causality Hypothesis (Subgroups)

		MLIEMP	NAVEMP
	Lags	Growth → SC	Growth → SC
France, Italy, Netherlands	1	0.4791	0.4895
	2	1.5707	1.8567 *
	3	1.2310	1.3883
	Lags	SC → Growth	SC → Growth
France, Germany, Italy, Netherlands, UK	1	1.0930	1.0780
	2	0.9874	0.9130
	3	1.0251	0.9528

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

None of the test statistics reaches the required critical values necessary to reject the null hypothesis of homogenous non-causality, irrespective of the direction of causality and the number of lags included. Hence, the finding of no causal relationship between growth and structural change in employment shares for these countries is further supported. For the remaining subgroup of Germany, Japan, the UK and the US where Granger-causality in the direction from growth to structural change in employment shares has been found, as well as for the subgroup of Japan and the US, where Granger-causality in the direction from structural change to aggregate economic growth has been found, the HC hypothesis was tested once again to find out whether these subgroups are homogenous. These results are presented in table 8.

Table 8. Test Results for Homogenous Causality Hypothesis (Subgroups)

		MLIEMP	NAVEMP
	Lags	Growth → SC	Growth → SC
Germany, Japan, UK, US	1	5.6659 ***	5.5941 ***
	2	2.0172 *	1.5037
	3	2.8415 ***	2.1133 **
Germany, UK, US	1	1.4829	1.3233
	2	1.3071	0.9705
	3	1.6890	1.2155
	Lags	SC → Growth	SC → Growth
Japan, US	1	0.0542	0.0257
	2	9.1462 ***	5.5366 ***
	3	12.9677 ***	8.3466 ***

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

For the first case of causality from growth to structural change the HC hypothesis can be widely rejected when all members of the subgroup Germany, Japan, the UK and the US are included. Once Japan is left out, the test fails to reject the HC hypothesis. Here one can draw two conclusions. On the one hand, there are similarities in the relationship between growth and structural change of the employment shares for Germany, the UK and the US. These countries appear to follow a similar pattern due to the fact that the HC hypothesis cannot be rejected. On the other hand, Japan seems to be different.[6] For the converse case of causality from structural change to economic growth the HC hypothesis can not be rejected for one lag but this result is not reliable for interpretation as homogenous causality in the light of the previous findings of the HENC hypothesis where it was not possible to reject the HENC hypothesis for Japan on at least a ten percent level. This is an indication that there does not exist any relationship for Japan with only one lag. Hence it might be that the causal relationship is stated to be homogenous because both, the Japanese and the US economy have an influence that is very close to zero for only one lag included. For two and three lags included the test results show a rejection of the HC hypothesis which indicates that the two economies are quite different in their causal relationships.

The analysis so far indicates that if structural change is measured in terms of employment changes between the three main sectors of an economy then aggregate economic growth does cause structural change in the but not the other way round when the lag length chosen equals one. When two or three lags are included the causality direction seems to be bi-directional. Once the HENC hypothesis is tested we found that Germany, Japan, the UK and the US show causality from economic growth to structural change measured in terms of employment irrespective of the lag length chosen. For the direction from structural change to economic growth only Japan and the US show significant results. Put that all together more evidence that aggregate economic growth causes structural change is given than vice versa.

But as already mentioned above, these causality tests give no clue about the sign of the influence. That means it is not stated whether economic growth speeds up or slows down structural change or whether structural change has a positive or negative impact on aggregate economic growth. Therefore the results of the underlying model estimates are investigated. It is hardly possible to interpret the results in the light of two opposing signs in an equation with two or more lags in aggregated form. Thus the lags are interpreted apart and the influence is interpreted as a very short run reaction for one lag and longer-term reactions for two or three lags. Furthermore the inclusion of two and three lags confirms the robustness of the findings

[6] This results were confirmed by doing the HC test for two of the economies each which is not reported in the table.

of the first specification where only one lag is included. Table 9 shows the signs of the estimated coefficients for the case of employment with the corresponding significance levels indicated by stars.

Table 9. Estimation Results of the HENC Hypothesis (Growth → SC)

	Modified Lilien Index (MLI)						Norm of Absolute Values (NAV)					
	1 Lag	2 Lags		3 Lags			1 Lag	2 Lags		3 Lags		
dlog(GDP)	-1	-1	-2	-1	-2	-3	-1	-1	-2	-1	-2	-3
France	+	-	+	-	+	-	+	-	+	-	+	-
Germany	- **	- ***	+ *	- **	+ **	+	- **	- ***	+ *	- **	+ **	+
Italy	+	+	+ **	+	+	+	+	+	+ **	+	+	+
Japan	+ **	-	+ *	-	+	+	+ **	-	+ *	-	+	+
Netherlands	-	-	- *	-	-	-	-	-	- *	-	-	-
UK	- **	- ***	+	- ***	+	-	- **	- ***	+	- ***	+ *	-
US	- **	- ***	+ **	- ***	+ **	+	- **	- ***	+ **	- ***	+ **	+

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

As stated by the test results above only Germany, Japan, the UK and the US have significant robust results. Thereby, only Japan indicates that a higher growth rate of real GDP in one period goes along with increasing structural change in the next period as it is suggested by structural change theory. But the inclusion of further lags weakens this coherence. Contrariwise, in Germany, the UK and the US high rates of economic growth in one period slow down structural change measured in terms of employment in the next period. This is also confirmed when additional lags are included. Hence economic growth does not accelerate structural change in the very short run. But, in the longer term structural change gets accelerating impulses from aggregate economic growth such that the overall effect is not clear from this analysis. This result an be additionally found for Italy but only when two lags are included. For the converse case that structural change causes economic growth table 10 reports the results of the corresponding estimation equations.

Table 10. Estimation Results of the HENC Hypothesis (SC→ Growth)

	dlog(GDP) (MLI)						dlog(GDP) (NAV)					
	1 Lag	2 Lags		3 Lags			1 Lag	2 Lags		3 Lags		
SCI	-1	-1	-2	-1	-2	-3	-1	-1	-2	-1	-2	-3
France	+	+	+	+	+	+	+	+	+	+	-	+
Germany	+	+	+	+	+	+	+	+	+	+	+	-
Italy	+	+	+	+	+	- **	+	+	+	+	+	- *
Japan	+	+	+ ***	+	+ ***	+	+	+	+ ***	+	+ ***	+
Netherlands	-	-	+	-	+	+	+	-	+	-	+	+
UK	+	+	-	+	-	+	+	+	-	+	-	+
US	+ **	+ ***	+ ***	+ ***	+ ***	+ *	+ **	+ ***	+ ***	+ ***	+ ***	+ *

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

Here only the results for the US are significant when only one lag is included. The influence is positive indicating that higher changes of the structure measured in terms of employment lead to higher rates of growth in the next period. This result also holds when additional lags are included. Even though not significant, these results are also found for the other investigated countries except the Netherlands. Higher rates of growth that succeed high structural change in the labor force indicate that these changes are not only due to changes in demand from productivity gaining sectors (industry) to sectors with slow productivity growth (services) as suggested by structural change theory. It seems to be the case, that structural change is a benefit for adjusting labor demand and labor supply. The idea that structural change slows down aggregate growth cannot be verified for any investigated economy. It seems to be the case that rigidities impede economic growth and structural change is needed for aggregate economic growth.

- *Results for Real Value Added*

This section reports the corresponding results for the case of real value added. As for the case of employment all results are shown for structural change measured by the MLI which is reported on the left hand side or NAV which is reported on the right hand side of the tables, respectively. Again all results are very similar for both indices used. In table 11 the results of the HNC hypothesis are displayed.

Table 11. Test Results for Homogenous Non-Causality Hypothesis (Real Value Added)

	Modified Lilien-Index (MLI)		Norm of Absolute Values (NAV)	
Lags	Growth → SC	SC → Growth	Growth → SC	SC → Growth
1	1.9122 *	3.2084 ***	1.8527 *	3.6162 ***
2	13.5389 ***	3.2509 ***	16.3336 ***	3.3726 ***
3	9.7641 ***	5.4352 ***	10.3523 ***	6.3997 ***

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

Opposed to the case of employment, the HNC shows in case of real value added measuring structural change more support for the causality direction from structural change to economic growth. For the inclusion of only one lag the hypothesis that growth does not cause structural change can only be rejected on a 10 percent level while the converse hypothesis that structural change causes economic growth can be rejected strongly. In the very short run, structural change appears to be more likely to cause aggregate economic growth than the other way round. Nonetheless, both hypotheses can be strongly rejected if more than one lag is included. Thus, the next step of analyzing homogeneity has to be turned to. In table 12 the results for the HC hypothesis for the case of real value added are presented.

Table 12. Test Results for Homogenous Causality Hypothesis (Real Value Added)

	Modified Lilien-Index (MLI)		Norm of Absolute Values (NAV)	
Lags	Growth → SC	SC → Growth	Growth → SC	SC → Growth
1	2.1517 **	2.8235 **	1.9983 *	3.3035 ***
2	5.8113 ***	2.9455 ***	7.8863 ***	3.1385 ***
3	6.5356 ***	4.9704 ***	7.4057 ***	5.4479 ***

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

As for the case of employment this hypothesis is rejected for the direction form aggregate economic growth to structural change, irrespective of the direction of causality and no matter which lag length is chosen. For the case that structural change causes aggregate economic growth, the test rejects now also for all specifications. As in the case of employment, these results imply again that the panel is heterogeneous and hence a deeper look at the country level is required. Table 13 presents the results of the HENC hypothesis test that stand in contrast to the case of employment.

Table 13. Test Results for Heterogeneous Non-Causality Hypothesis (Real Value Added)

		Modified Lilien-Index (MLI)		Norm of Absolute Values (NAV)	
	Lags	Growth → SC	SC → Growth	Growth → SC	SC → Growth
France	1	0.5577	0.5709	0.2252	0.6110
	2	40.6583 ***	0.4112	60.5815 ***	0.4277
	3	39.3098 ***	0.2050	44.5878 ***	0.2041
Germany	1	0.2022	3.7680 *	0.1906	4.3028 **
	2	3.1363 **	2.0420	3.0770 **	2.2331
	3	2.7318 **	0.9247	2.4664 *	0.9711
Italy	1	0.3665	9.0054 ***	0.4359	9.7467 ***
	2	0.0823	6.3434 ***	0.1199	6.5930 ***
	3	1.6751	8.6707 ***	2.4051 *	9.0749 ***
Japan	1	2.0435	1.1286	2.6900	1.4993
	2	29.9547 ***	4.6161 **	28.8252 ***	4.6486 **
	3	4.9726 ***	4.1505 ***	3.4437 **	4.5613 ***
Nether-lands	1	5.3085 **	0.5212	5.0255 **	0.4994
	2	6.0091 ***	0.4907	6.6174 ***	0.5516
	3	3.8469 **	1.4206	3.4655 **	1.3389
UK	1	0.1872	0.0974	0.1266	0.1243
	2	9.7181 ***	0.4763	9.4688 ***	0.4479
	3	3.6808 **	16.5741 ***	3.7525 **	22.8296 ***
US	1	4.5242 **	6.8635 ***	3.9668 **	7.8780 ***
	2	1.4893	4.8807 ***	1.4559	4.9655 ***
	3	2.3499 *	7.8294 ***	2.6729 **	8.1618 ***

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

If only one lag is included, support that economic growth causes structural change is given only for the Netherlands and the US. If two or more lags are included, also France, Germany, Japan and the UK show a causal relationship from economic growth to structural change but this relationship becomes weaker for the US. Only for the Netherlands the results are independent of the lag length chosen. Structural change causes economic growth in Italy and the US, irrespective of the lag length chosen. Germany gives weak support in the case of one lag. Japan is only able to reject when two or three lags are included and the UK rejects on for a lag length of three only. For France and the Netherlands the direction of causality is from economic growth to structural change. For Italy the opposite direction that structural change causes economic growth is found. For the remaining countries Germany, Japan, the UK and the US a bi-directional causality structure seems to be at work even if it is very heterogeneous across these countries and in some cases very weak.

In sum, the results stand in line with the results of the case of employment. The HNC hypothesis shows that the causality seems to be be-directional as in the case of employment. In the very short run, it is slightly more evidence given, that structural change causes aggregate economic growth than vice versa in the case of real value added. In the longer term, aggregate economic growth has an impact on structural change for most of the countries. The hypothesis that structural change does not cause aggregate economic growth can be rejected for Italy, the US and Germany in the short run, even if only with weak power in the latter case. In the longer term, it can be rejected additionally for Japan and the UK, but not for Germany anymore.

As in the case of employment the investigation of the signs the estimated parameters shall shed some more light on the direction of action. Table 14 displays the signs of the coefficient estimates of the HENC equations concerning the direction growth causes structural change.

Table 14. Estimation Results of the HENC Hypothesis (Growth → SC)

	Modified Lilien Index (MLI)						Norm of Absolute Values (NAV)					
	1 Lag	2 Lags		3 Lags			1 Lag	2 Lags		3 Lags		
dlog(GDP)	-1	-1	-2	-1	-2	-3	-1	-1	-2	-1	-2	-3
France	-	- ***	+ ***	+	+ ***	- ***	-	- ***	+ ***	+	+ ***	- ***
Germany	-	-	+ **	-	+ ***	+	-	-	+ **	-	+ ***	+
Italy	-	-	+	-	+	+	-	-	+	-	+	+
Japan	+	+	+ **	-	+	+	+	+	+ **	-	+	+
Netherlands	+ **	+	+ ***	+	+	-	+ **	+	+ ***	+	+	-
UK	-	-	+ ***	+	+ **	-	-	-	+ ***	-	+ **	-
US	- **	- *	-	-	-	+	- **	-	-	-	+	+

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

For the first specification, where only one lag is included, significant results are found only for the Netherlands and the US, whereby the direction of action is positive for the Netherlands and negative for the US. With the additional inclusion of a second lag in the second specification, the significance disappears for the Netherlands and decreases for the US in the first lag. As in the case of employment the impact for Germany, the UK and the US is negatively in the very short run even though only significant for the case of the US. With additional lags included the impact is positive as in the case of employment for Germany and the UK. Contrary to the case of employment we found significant results also for France and the Netherlands. While the Netherlands stands in line with the other investigated countries, the results for France are ambiguous. Summarized the longer-term influence of growth on structural change is positive as in the case of employment. An exception is the US where the influence remains negative even though not significant.

Put it all together, we can state that aggregate economic growth has a significant positive influence on structural change in the longer term as in the case of employment. For the very short run we cannot confirm the results of employment but it seems to be the case that growth is decelerating structural change here, too. Table 15 displays the results for the opposite case that structural change causes economic growth.

Table 15. Estimation Results of the HENC Hypothesis (SC → Growth)

	dlog(GDP) (MLI)						dlog(GDP) (NAV)					
	1 Lag	2 Lags		3 Lags			1 Lag	2 Lags		3 Lags		
SCI	-1	-1	-2	-1	-2	-3	-1	-1	-2	-1	-2	-3
France	+	+	-	+	-	-	+	+	-	+	-	-
Germany	+ *	+ *	+	+	+	-	+ **	+ *	+	+	+	-
Italy	+ ***	+ ***	- ***	+	-	+ **	+ ***	+ ***	- ***	+	-	+ **
Japan	-	+	+ ***	+	+ ***	+ **	-	+	+ ***	+	+ ***	+ ***
Netherlands	+	+	+	+	+	+	+	+	+	+	+	+
UK	-	-	-	-	-	+ **	-	-	-	-	-	+ **
US	+ ***	+ ***	+	+ ***	+	+ ***	+ ***	+ ***	+	+ ***	+	+ ***

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

For the first specification, where only one lag is included, a positive influence of structural changes measured in terms of real value added on economic growth can be found for the US, Italy and Germany, even though it is weak significant for the latter. The inclusion of two lags in the second specification does not change the results for these countries. Now Italy and Japan get significant estimates for the second lag. In the third specification significance vanishes for Germany and the UK gets a significantly positive dependence of the third lag as well as Italy, Japan and the US.

In sum aggregate economic growth has a positive impact on structural change in the longer term as it is the case for employment. The short run negative effect is not as strong as in the case of employment. For the direction from structural change to aggregate economic growth the results found for real value added do also widely confirm the results of employment. Again, we found a significant positive influence and no evidence for the opposite case that aggregate economic growth is negatively affected, except Italy, where the aggregate effect is not clear.

6 Conclusion

This paper investigated the causal relationship between economic growth and structural change measured in terms of employment as well as in terms of real value added by the aid of a Granger causality test in a panel framework for seven OECD countries. The main finding is that the causality relationships are heterogeneous across the investigated countries. We found evidence that aggregate economic growth is causing structural change as well as the other way round.

For the case that aggregate economic growth causes structural change significant results were found for the largest economies Germany, Japan, the UK and the US measured in terms of employment as well as in terms of real value added while the results for the other countries depend on the measure of structural change. For the largest economies we found that economic growth is decelerating structural change in the following period while it is accelerating it with a lag of two and three years. For the remaining countries the results are similar. When causality could be obtained the results are in the same direction. Unfortunately the sum of effects could not be measured in this way of analysis. Put it all together, we found out that structural change is induced by economic growth as it is predicted by theory.

For the reverse case that structural change causes economic growth the results are different. For the case of employment we found significantly positive results only for Japan and the US measured in terms of employment while all remaining countries have no significant results irrespective of the lag length chosen. In the case of real value added additionally significantly positive results were found additionally for Italy, Germany and the UK, even though very weak for the latter. The remaining countries are still insignificant in their results.

In sum, the estimates yields to the result that structural change is not decelerating structural change for any investigated country, irrespective whether structural change is measured in terms of employment or in terms of real value added. The disease as described by Baumol and others seems not to occur. Rather it appears to be the case, that rigidities impede economic growth and therefore structural change is needed for aggregate economic growth. Therefore it would be very interesting to investigate why structural change has a significantly positive influence in Japan and the US while it is not significant in the European countries. For research dealing with the topic of structural and economic growth it has been shown, that growth is important for structural change as well as the other ay round.

Of course, the theoretical considerations involve only the verbal stated theoretical aspects of earlier contributions to economic growth and structural change. The results of the empirical

investigation require more detailed explanations of the channel through which economic growth affects structural changes in the major sectors of the economy either measured in terms of employment or in terms of real value added. Beside the interpretation of the signs is not sufficient to be able to make statements about the influence when the sign of the estimates is opposing in different periods. Therefore in a next step it will be tried to find a way to aggregate the estimation results. Moreover, the number of investigated economies shall be raised in order to get more insights of the heterogeneity of the economies.

Appendix 1: Data

The macroeconomic values used in the body of this paper are real GDP expressed in prices from 2000 and deflated by using the Laspeyres-Index from the Penn World Table (PWT) revision 6.2 (see Heston et al. (2006)). I decided to use this time series instead of the real GDP deflated by using the Chain-Index because the corresponding sectoral data are also deflated by using the method of Layspeyres. Nonetheless all computations were also done by using the real GDP data deflated by the Chain-Index with almost the same results. Additionally, all computations were done by using real GDP data expressed in 1990 International Geary-Khamis dollars taken from Maddison (2007) as well as using real GDP in prices from 1995 taken from the EU KLEMS database (Timmer et al. (2008)) which did not change the results, too.

Data are available for all countries from 1950 until 2004 with the exception of Germany. Here only the period from 1970 until 2004 was available such that an extrapolation until 1950 was necessary. Therefore we used the time series of West-Germany in the older version 5.6 of the PWT (Heston et al. (1995)) and calculated growth rates from 1950 until 1970 with the additional assumption that the trends of West-Germany can be linked to the Unified Germany series afterwards. This is exactly the procedure in the PWT 6.2 from 1970 until 1991 and the time series of the EU KLEMS database are constructed in the same way.

Sectoral data in terms of real value added and employment are taken from the EU KLEMS database as well as from the ten-sector database of the Groningen Growth and Development Centre (GGDC) (van Ark (1996)). In the former, time series data are available from 1970 (except real value added for Japan: from 1973) until 2004 disaggregated to a two-digit level of NACE 1.1. The sectors were aggregated to the three main sectors as it can be seen in the following table A1.

Table A1. Aggregation of the Three Main Sectors Using Data in the NACE Rev.1 Classification

Sector	Code	Name
Primary	AtB C	• Agriculture, Hunting, Forestry and Fishing • Mining and Quarrying
Secondary	D E F	• Total Manufacturing • Electricity, Gas and Water Supply • Construction
Tertiary	G H I JtK O P	• Wholesale and Retail Trade • Hotels and Restaurants • Transport and Storage and Communication • Finance, Insurance, Real Estate and Business Services • Other Community, Social and Personal Services • Private Households with Employed Persons
Left Out	L M N	• Public Admin and Defence; Compulsory Social Security • Education • Health and Social Work

For this division there appeared only a few minor data gaps and data problems. For the case of Japan there are no values given for P ("private households with employed persons") so that these values are assumed to be zero. In the case of the United States the deflator values of P are missing. Those values were taken from another table ("USA NAICS Basic 07I") which is also available at the EU KLEMS database. Unfortunately this time series is only available from 1977 until 2004. After an intensive comparison with the other countries the similarity of the price development in this sector with the price development of the same sector in Germany justifies the assumption that the growth rate of the deflator of Germany is close to the growth rate of the US such that the time series can be extrapolated back with these values from 1976 back to 1970.

The ten sectors of the second data source had been aggregated to the three main sectors in a first step. The primary sector consists of agriculture and mining, the secondary includes manufacturing, public utilities and construction and the tertiary sector consists of wholesale and retail trade, transport and communication, finance, insurance and real estate and community, social and personal services. Government services have been left out. The time series of the ten-sector database are available for the economies as listed in the following table A2.

Table A2. 10-Sector Database: Data Availability

Country	Employment	Real Value Added (1985 prices)
France	1954-1996	1950-1996
Germany	1950-1997	1950-1997
Italy	1951-1996	1951-1996
Japan	1953-1996	1953-1996
Netherlands	1960-1998	1960-1998
UK	1948-1996	1947-1996
US	1950-1997	1947-1997

To match both the EU KLEMS database and the ten-sector database we perused the following strategy. After calculating the sector shares in a first step both time series were visually examined concerning their similarity in share and development during the overlapping period. Then the growth rates of the absolute sectoral aggregate values of the ten sector data were calculated to extrapolate the EU KLEMS time series. For comparison the same procedure has also been applied to the growth rates of the sector shares.

Appendix 2: Unit-Root Test Results

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

a) for common unit roots in panel data

- Levin, Lin and Chu (2002)
- Breitung (2000)

b) for individual unit roots panel data

- Im, Peseran and Shin (2003)
- Fisher-type test using the ADF test (Maddala and Wu (1999))
- Fisher-type test using the PP test (Choi (2001))

c) for time series

- ERS point optimal test of the unit-root null hypothesis (Elliot et al. (1996))

In the subsequent tables the results of these six tests are reported for each of the five variables, the modified Lilien-index for employment and real value added, the norm of absolute values for employment and real value added, and for the growth rate of GDP. Autocorrelation is controlled for up to three lags in the test regressions and window widths. To demonstrate 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 are computed. The test results of the panel unit root tests are shown in table A3.

Table A3. Results for Panel Unit Root Tests

		Growth	Modified Lilien Index (MLI)		Norm of Absolute Values (NAV)	
	L/BW	dlog(GDP)	Employment	Value Added	Employment	Value Added
Common Unit Roots						
Levin, Lin and Chu	0	-10.6940 ***	-9.9678 ***	-15.0462 ***	-10.3659 ***	-14.1637 ***
	1	-7.6327 ***	-5.1589 ***	-9.8825 ***	-5.4152 ***	-9.0358 ***
	2	-3.7108 ***	-3.8890 ***	-7.1479 ***	-4.2875 ***	-6.1791 ***
	3	-1.7865 **	-2.8219 ***	-4.0933 ***	-3.1688 ***	-2.8412 ***
Breitung	0	-8.8652 ***	-8.1134 ***	-9.2842 ***	-8.2763 ***	-9.0796 ***
	1	-8.4336 ***	-5.7656 ***	-5.1146 ***	-5.7594 ***	-4.9435 ***
	2	-5.4185 ***	-3.7875 ***	-1.9040 **	-3.6603 ***	-1.8168 **
	3	-2.9446 ***	-2.8214 ***	-1.0413	-2.6887 ***	-0.9237
Individual Unit Roots						
Im, Pesaran and Shin	0	-11.7059 ***	-8.9151 ***	-12.9236 ***	-9.0571 ***	-12.7691 ***
	1	-9.6905 ***	-5.2801 ***	-8.9074 ***	-5.2609 ***	-8.9511 ***
	2	-6.2153 ***	-4.5544 ***	-7.0611 ***	-4.6278 ***	-7.1655 ***
	3	-4.7656 ***	-3.8357 ***	-5.0006 ***	-3.8807 ***	-5.0202 ***
Fisher - ADF	0	130.3690 ***	103.2840 ***	161.8080 ***	105.0110 ***	159.4070 ***
	1	105.8230 ***	59.4174 ***	103.9530 ***	58.7398 ***	104.4840 ***
	2	62.8160 ***	48.6771 ***	76.8776 ***	48.8824 ***	78.4448 ***
	3	47.3781 ***	40.0685 ***	51.8611 ***	40.2496 ***	52.4045 ***
Fisher - PP	0	130.3690 ***	103.2840 ***	161.8080 ***	105.0110 ***	159.4070 ***
	1	131.3890 ***	100.7530 ***	162.0890 ***	102.4730 ***	159.6040 ***
	2	128.8670 ***	101.6550 ***	161.4280 ***	103.6020 ***	158.7500 ***
	3	128.1260 ***	102.2770 ***	160.8610 ***	104.1060 ***	158.1350 ***

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

The test statistics of the Levin, Lin and Chu test reject the null-hypothesis of a common unit root process for all variables on a level above 99 percent irrespective of the number of lags. A similar outcome is also given for the Breitung-test, except that this test does not reject the null

hypothesis for the case of real value added with three lags chosen probably to a loss of power. Summarizing these findings one can conclude that nonstationarity is not an issue of any of the panel series.

The three panel unit root tests for individual unit roots, namely the IPS test, the Fisher-ADF and the Fisher-PP test reject the null hypothesis that all series contain a unit root process for all variables and irrespective of the lags chosen. Table A4 displays the results for the ERS point optimal test of the unit-root null hypothesis for all variables with one to three lags, respectively.

Table A4. Results for ERS Unit Root Test

		Growth	Modified Lilien Index (MLI)		Norm of Absolute Values (NAV)	
	Lags	dlog(GDP)	Employment	Value Added	Employment	Value Added
France	0	-3.0549 ***	-3.6547 ***	-5.6755 ***	-3.5940 ***	-5.6978 ***
	1	-2.0972 **	-3.2010 ***	-4.1165 ***	-3.1882 ***	-4.1095 ***
	2	-1.4481	-2.0100 **	-2.9294 ***	-2.0782 **	-2.9399 ***
	3	-1.4934	-1.8572 *	-2.3137 **	-1.9484 *	-2.3739 **
Germany	0	-3.9036 ***	-4.2006 ***	-6.1969 ***	-4.2521 ***	-6.2396 ***
	1	-4.0440 ***	-3.8186 ***	-5.0100 ***	-3.8548 ***	-5.1877 ***
	2	-2.2708 **	-2.9672 ***	-2.9501 ***	-2.9605 ***	-3.0390 ***
	3	-1.9700 **	-2.5842 **	-2.9612 ***	-2.5796 **	-2.9627 ***
Italy	0	-2.9212 ***	-2.9497 ***	-5.9197 ***	-3.0176 ***	-5.6827 ***
	1	-1.8412 *	-1.6912 *	-3.5279 ***	-1.7038 *	-3.5409 ***
	2	-1.0297	-1.5674	-2.9266 ***	-1.5569	-2.8627 ***
	3	-0.6028	-1.3200	-2.3544 **	-1.3283	-2.3335 **
Japan	0	-1.9838 **	-2.3444 **	-6.2687 ***	-2.5516 **	-6.0962 ***
	1	-1.3026	-1.1393	-5.1433 ***	-1.3137	-4.9266 ***
	2	-0.6593	-1.1464	-3.0521 ***	-1.5005	-2.8552 ***
	3	-0.8654	-0.8923	-2.5260 **	-1.2240	-2.2760 **
Netherlands	0	-3.3892 ***	-3.5500 ***	-4.5606 ***	-3.6267 ***	-4.5598 ***
	1	-2.6838 ***	-2.6205 ***	-3.8424 ***	-2.4863 **	-3.6959 ***
	2	-2.2642 **	-3.0057 ***	-3.5664 ***	-2.9723 ***	-3.5162 ***
	3	-2.7590 ***	-3.1015 ***	-3.0406 ***	-3.0066 ***	-3.0057 ***
UK	0	-4.8013 ***	-3.8949 ***	-4.8568 ***	-3.9934 ***	-4.8652 ***
	1	-4.7483 ***	-2.6387 ***	-3.2775 ***	-2.5823 **	-3.3811 ***
	2	-3.6945 ***	-2.7853 ***	-2.8946 ***	-2.7260 ***	-3.0616 ***
	3	-4.0692 ***	-2.7599 ***	-2.4986 **	-2.7352 ***	-2.5206 **
US	0	-4.9346 ***	-6.2246 ***	-3.9683 ***	-6.2743 ***	-3.9896 ***
	1	-4.8378 ***	-4.9620 ***	-3.6122 ***	-4.8271 ***	-3.5794 ***
	2	-4.0791 ***	-4.7881 ***	-2.9788 ***	-4.5961 ***	-2.8938 ***
	3	-3.7583 ***	-3.4976 ***	-2.3769 **	-3.3504 ***	-2.4245 **

Note: significance denoted by *** on 1%, ** on 5% and * on 10% level.

The unit root hypothesis can be rejected for all variables and all investigated countries at one lag. The robustness check yields the same results for two and three lags, respectively for all variables for Germany, the Netherlands, the UK and the US. Furthermore, it holds for the structural change indices of real value added with two and three lags for the remaining countries, too. But the evidence for the growth rate of GDP and the structural change indices for the case of employment are not as strongly supported for France, Italy and Japan.

To judge these finings, a visual inspection of the time series may help. Figures A1 and A2 show the time series for the growth rate of real GDP and the structural change indices for all seven countries also shows a close agreement of the two structural change indices. In sum we interpret the whole set of results as well as the visual findings of the time series as evidence in favor of stationarity of all variables.

Figure A1. Growth Rate of Real GDP 1960-2004

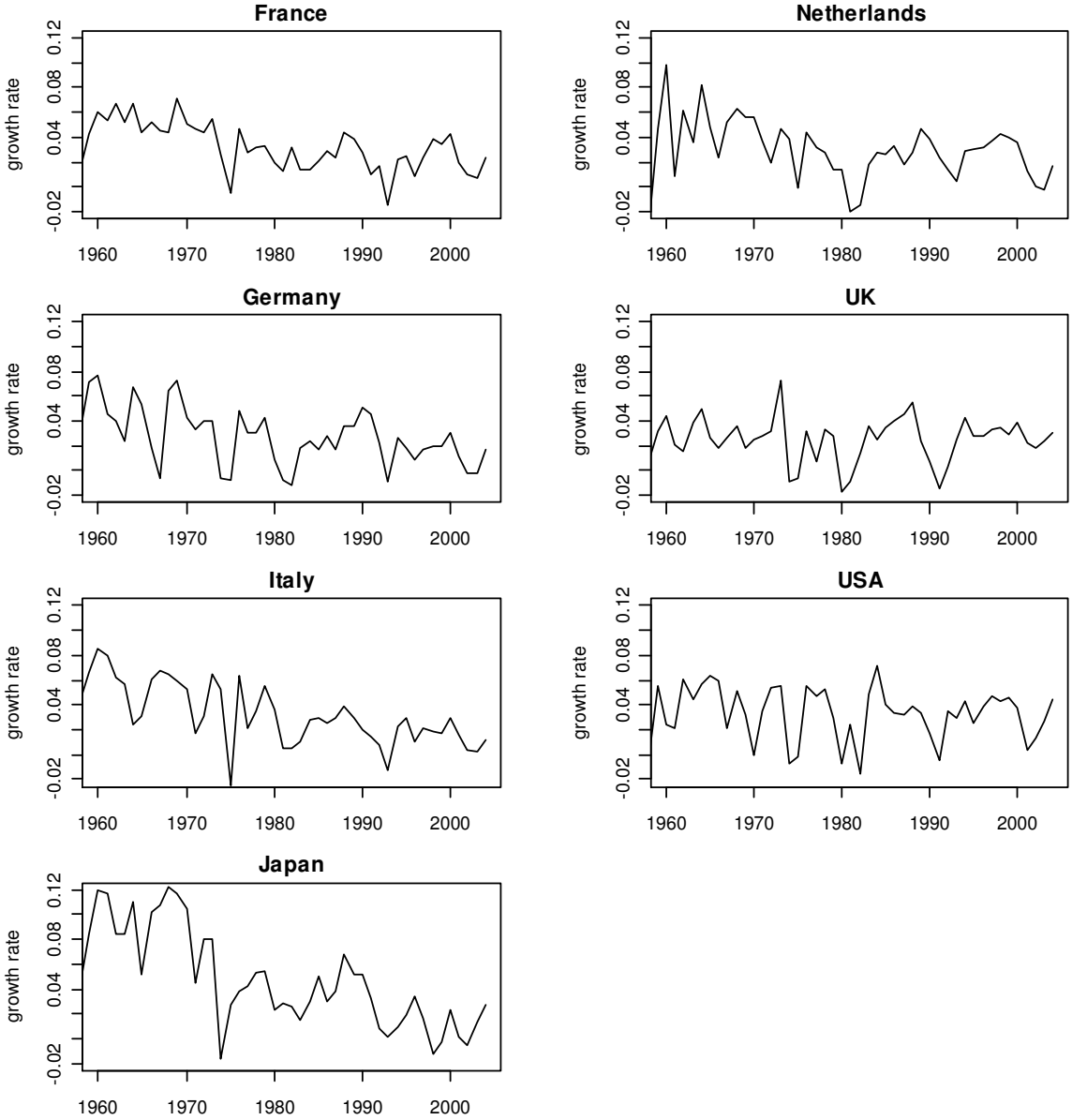
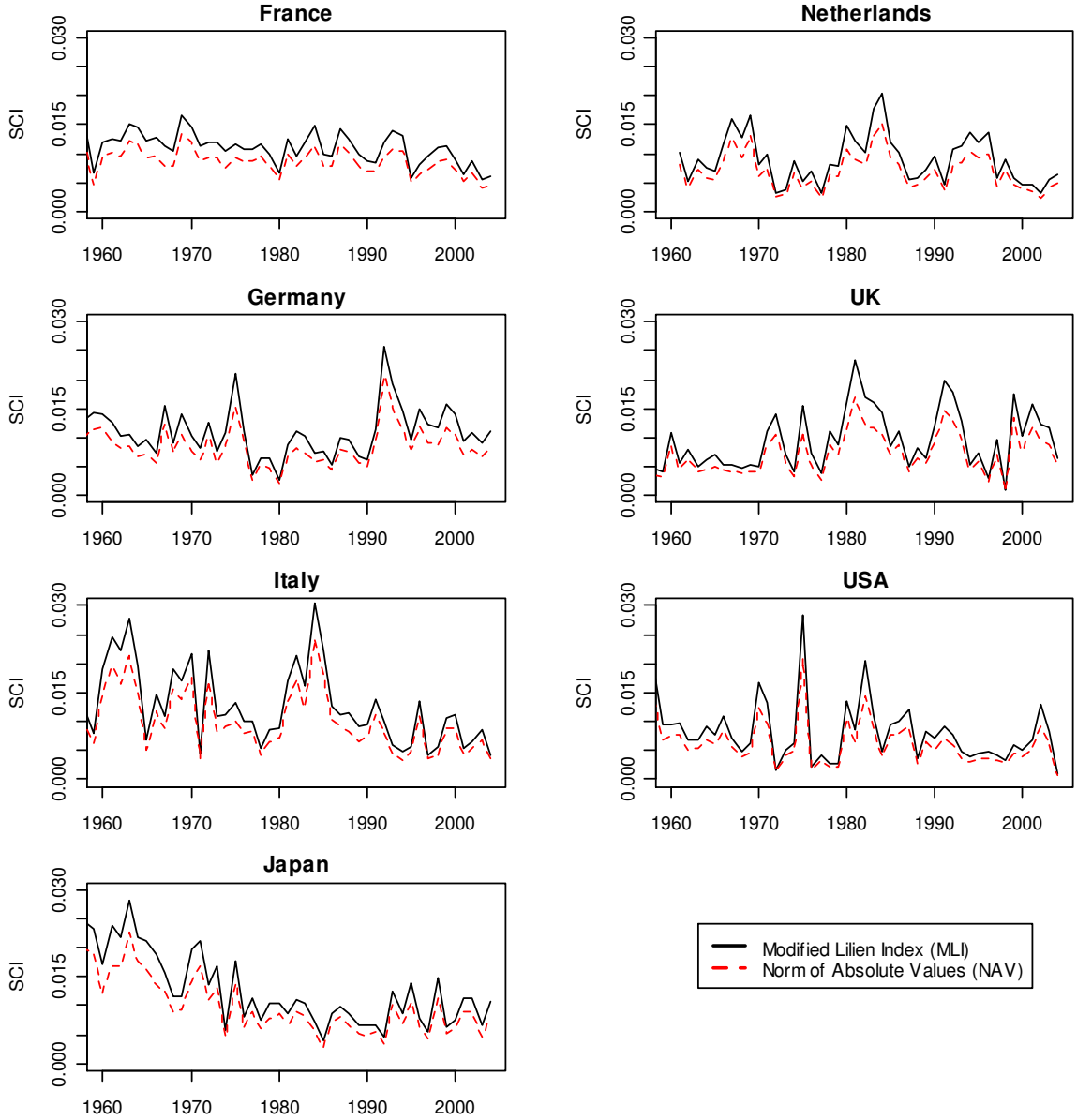


Figure A2. Structural Change Indices Employment 1960-2004



Appendix 3: Development of the Sector Shares

Figure A3. Development of Employment Shares from 1960 until 2004

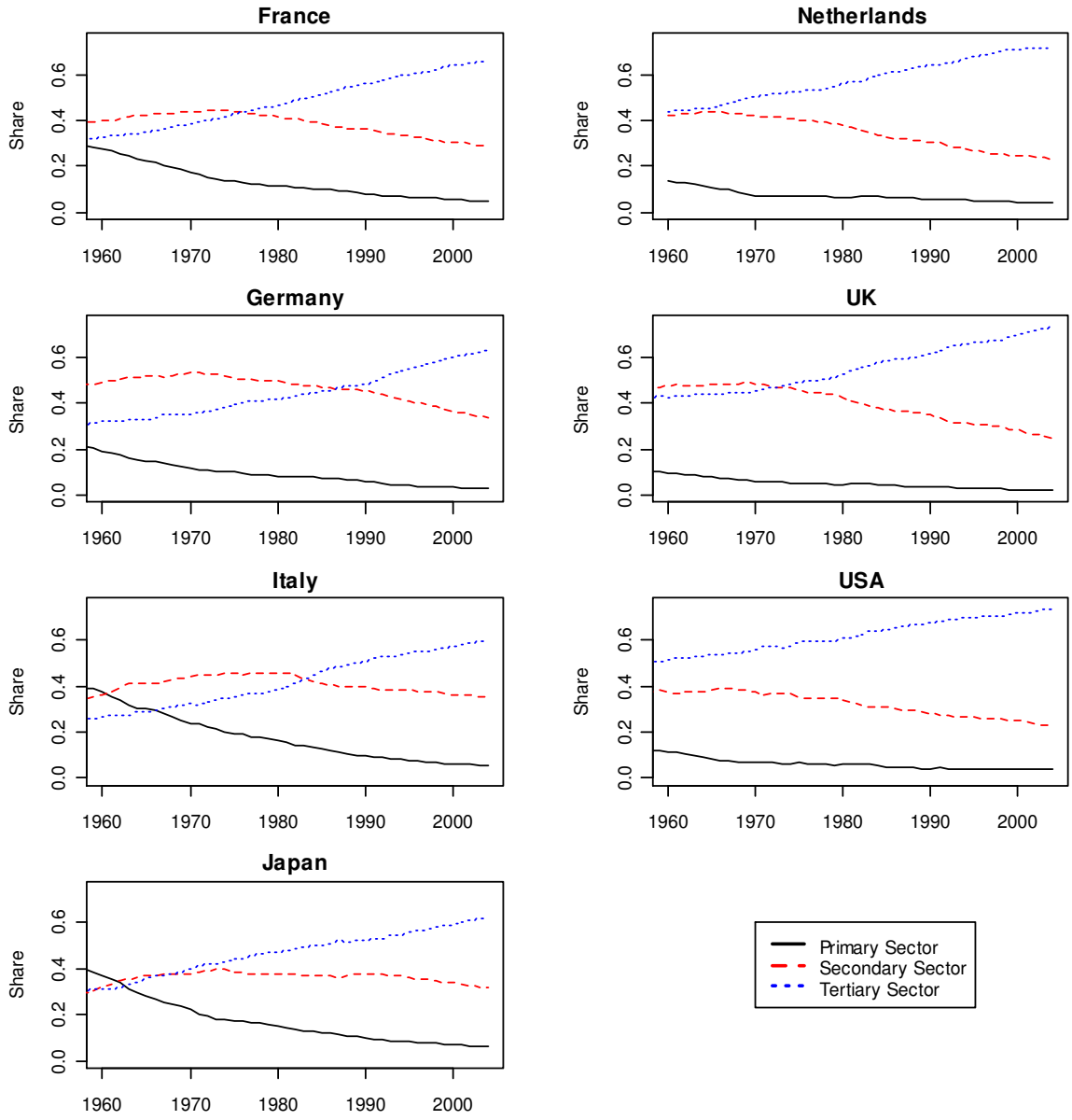
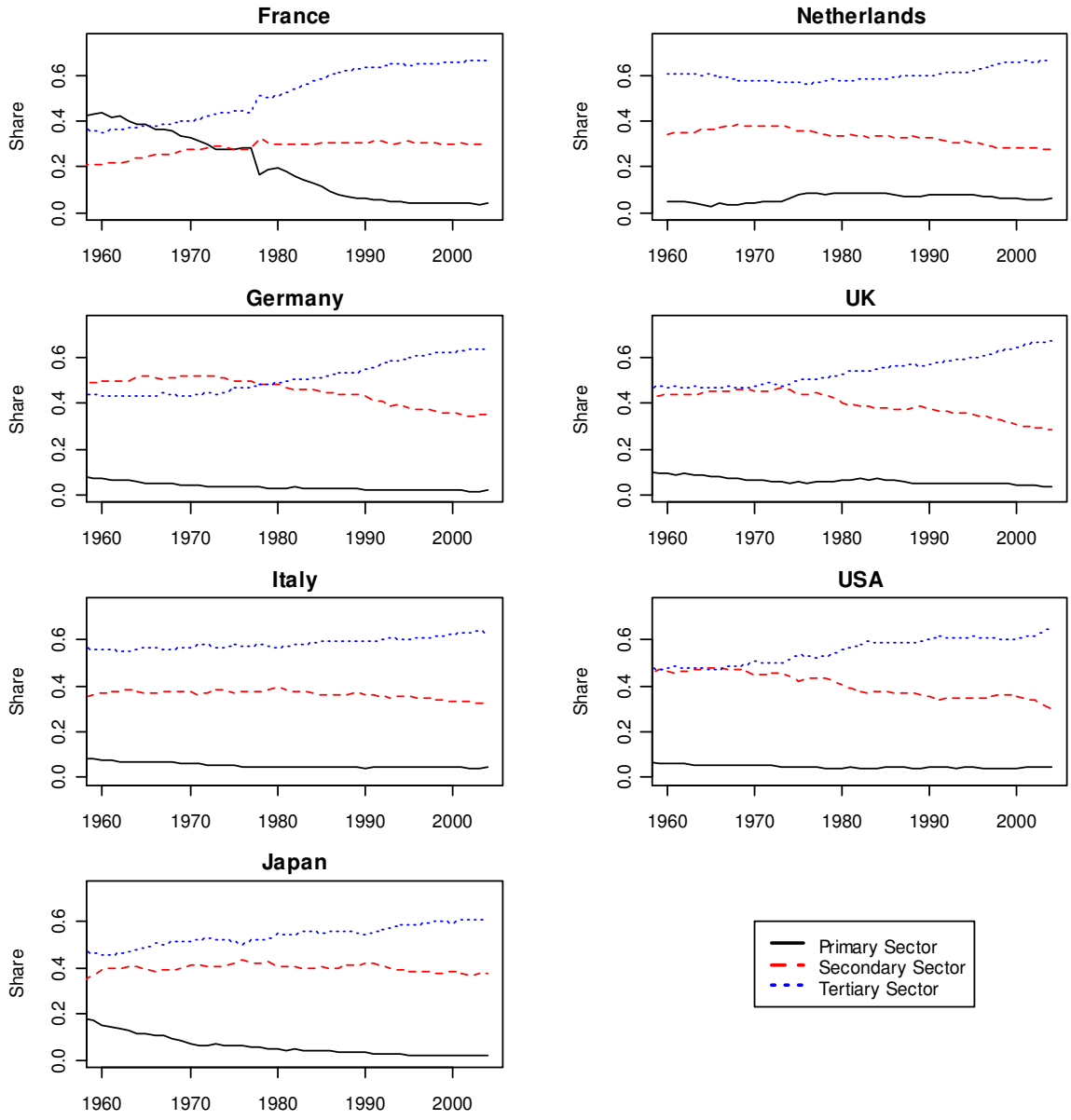


Figure A4. Development of Real Value Added Shares from 1960 until 2004



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