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International sectoral spillovers: An empircal analysis for German and US Industries

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An Empirical Analysis for German and U.S. Industries

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Preliminary, comments most welcome

Abstract:

In the paper, productivity convergence is analyzed with a broad panel of industry sector data for the United States and Germany for 1960–1990. The time-series/cross-sectoral data set allows to investigate country-specific convergence, and to control for sector-specific differences in human capital and factor utilization. It is found that the technological distance had a significant effect on German sectoral productivity growth in the sixties and seventies. Some part of the catching-up is due to capital-deepening, but most of it is total factor productivity convergence, i.e. endogenous growth models relying on knowledge spillovers receive support by the estimates. In addition, being behind had a significant impact on sectoral prices and employment in Germany.

Keywords: Endogenous growth, sectoral spillovers, convergence

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1 Introduction

The recent development of endogenous growth theories has renewed the interest into the sources of productivity growth of the advanced industrialized economies after World War II. The most outstanding stylized facts of the economic development were the extraordinary high growth rates of labour productivity and total factor productivity (TFP) during the first quarter-century after the war. However, growth rates slowed down since the beginning of the seventies in most of the advanced countries. In addition, the United States, who "... was the world's most productive economy by virtually any measure"[1] for a long time after the war experienced a much slower rate of productivity advance almost during the whole period, which has lead to a discussion about the loss of technological leadership.[2]

The most prominent hypothesis for this development is the catching-up of the follower countries with respect to the leader, the United States.[3] After the war, the United States employed the most sophisticated techniques for production, and the increasing international co-operation through trade and foreign direct investment opened the opportunity for the followers to catch up. The waning of opportunities for catching-up then offers a partial explanation for the observed slowdown of productivity growth since the seventies for the follower countries.

A theoretical background for the catching-up hypothesis is found both in the neoclassical growth model a la Solow[4] and in the recent theories of endogenous growth. In neoclassical growth models, a country's labour productivity growth rate tends to be inversely related to its starting level due to diminishing returns to reproducible capital. Then catching-up is simply convergence of capital-labour ratios. A related argument relevant to the convergence debate is reconstruction growth.[5] After the war, a large gap existed between actual output and the technological potential of many European countries and Japan. A part of the high growth of these countries in the early post-war period may therefore be attributed to the closing of this gap. Endogenous growth models, in contrast, focus on knowledge spillovers and vanishing differences of total factor productivity levels.[6] Beside the apparent result of productivity convergence, however, both models differ sharply in their implications and policy recommendations. Knowledge spillovers imply an externality, because firms do not receive full compensation of their research effort. Promoting R&D therefore may increase welfare. In addition, knowledge spillovers from abroad supply an argument in favour of a policy which promotes international cooperation

[1] Nelson, Wright (1992), p.1931.
[2] See ibid. and Baumol, Blackman, Wolff (1989).
[3] See e.g. Abramovitz (1986), Maddison (1987), Dowrick, Nguyen (1989), Wolff (1991).
[4] Solow (1956, 1957).
[5] See Dumke (1990).
[6] See e.g. Romer (1994), Grossman, Helpman (1994), and Coe, Helpman (1995) for recent overviews.

through trade and foreign direct investment.

Despite the enormous body of empirical literature on this theme, and the growing availability of comparable international data sets, empirical results for the relative importance of those hypotheses are still ambiguous.[7] Catching-up and convergence were found in nearly all studies, at least for the OECD countries, but while e.g. Mankiw, Romer, Weil (1992), p. 407, found that "... an augmented Solow model that includes accumulation of human as well as physical capital provides an excellent description of the cross-country data", Dowrick, Nguyen (1989), p. 1028, conclude that "... TFP catch-up stands out as a dominant and stable trend."

The main contribution of this paper is the empirical investigation of these issues for a broad panel of industry-sector data for West Germany, i.e. the former Federal Republic of Germany, and the United States. The OECD provides comparable sectoral data for these countries for the period from 1960 to 1990.[8] The analysis focuses on productivity convergence within a production function framework. The main emphasis of the paper is on the identification of the importance of technological spillovers for this process at the industry level.

Very few empirical papers on convergence employ panel data, even though the use of time-series/cross-industry data can help to identify the relative impact of the different sources of productivity growth; it allows to take into account country-specific differences of the adjustment process and complements the work on convergence of labour productivity levels at more aggregate levels.[9] For instance, one result from cross-country studies is that convergence is found for some country groups (i.e. the OECD-countries) but not for others, and it is anything but obvious that the speed of convergence should be equal for all countries. In addition, cross-industry data exibit a larger degree of comparability as compared to cross-country data. The time-series dimension of the data permits the analysis of the impact of the business cycle on long-run growth and to look for differences according to the time period under investigation.

Another aim of the paper is to identify further effects of productivity differences on the development of the technologically less advanced sector. Knowledge spillovers tend to increase productivity growth of the follower. On the other hand, market penetration of technologically more advanced foreign firms may result in lower growth of the domestic sector and in a concentration on activities with less comparative disadvantage, i.e. low tech activities. The question which effect dominates has important policy consequences, for instance for industrial policy or trade policy with Japan.

[7] See e.g. Romer (1989), Dowrick, Nguyen (1989), Barro (1991), and Mankiw, Romer, Weil (1992). Levine, Renelt (1992) and Sala-i-Martin (1994) gave a critical assessment. The mostly used data sources are the Penn World Tables from Summers, Heston (1991) and Maddison's (1982,1987) long-run data.

[8] See OECD (1993) and Meyer-zu-Schlochtern, Meyer-zu-Schlochtern (1994).

[9] For instance, the "growth miracle" of Germany (and Japan) after World War II is sometimes cited as an outlier. See Dowrick, Nguyen (1989).

2 Theoretical framework

2.1 Post-war growth in Germany and the United States

In the early post-war period, the United States was the productivity leader in virtually every industry.[10] In 1950, the level of GDP per hour worked in the United States was about twice as high as the productivity level of the major European countries, three times as high as Germany's, and seven times as high as in Japan.[11] The following reasons are cited for this lead:[12]

- The destruction of a large part of the productive capacities and economic institutions in many European countries, especially in Germany, and in Japan during the war. For instance, the capital-labour ratio was much higher in the United States than in those countries.[13]

- The availability and the techniques of exploiting natural resources in the United States.

- The third and perhaps the most important argument are the economies of a large market which allow to take advantage of scale economies and knowledge spillovers. A part of the lead is e.g. reflected in the dominance in mass production industries of the United States, another part is reflected in the massive R&D investments.

In Germany, reconstruction started soon after the end of the war. Although production grew from late 1945 onward, the foundations for the economic development were laid with institutional changes such as the currency reform, the partial dismantling of wartime controls, and the announcement of the Marshall Plan in 1948.[14] Soon afterwards, at the beginning of the fifties, the capital stock, GDP, and labour productivity reached pre-war levels, and during the fifties, Germany experienced a period of rapid growth with about a doubling of the capital stock, output, and labour productivity.[15] Full employment was achieved at the beginning of the sixties. Since then, German productivity growth was more or less within the average of the other OECD-countries. Therefore, the waning of most effects stemming from reconstruction can probably be dated to the end of the fifties.[16]

The most prominent hypothesis for the catching-up of the follower countries after the war is that the reasons for the technological leadership of the

[10] See Dollar, Wolff (1988), p. 552.
[11] Detailed data are contained in Maddison (1982, 1987).
[12] For a recent overview of the debate, see Nelson, Wright (1992).
[13] See Wolff (1991).
[14] See Hennings (1982).
[15] For a detailed data survey, see Maddison (1982, 1987), Wolff (1991). Krengel (1958) contains detailed German pre- and post-war data .
[16] For a detailed discussion, see Dumke (1990). A similar conclusion was reached by Dowrick, Nguyen (1989). Maddison (1987) dated the end of reconstruction of the European countries at 1950, but mentioned Germany (and Japan) as outliers.

United States had eroded.[17] First, a non-negligible part of catching-up had occurred in the early post-war period, and was strongest in those countries that were mostly damaged during the war. For instance, the strongest results in favour of convergence were achieved for the OECD-countries, and the highest productivity growth within this group in the fifties had occurred in Japan, Germany, Austria, and Italy.[18] Of course, "pure" reconstruction was probably responsible only for a small part of the economic success of those countries, since pre-war productivity levels were achieved already at the beginning of the fifties. However, the technological development had not stopped during the war. In Germany, for instance, annual war-time investments in the investment goods industry were more than twice the value of 1936/37.[19] In addition, the high growth during the reconstruction period after the war had created an economic atmosphere with demand increases, moderate wage growth, and high physical and R&D investment, and endowed those countries with a modern, high-quality capital stock.

These reconstruction effects can be easily reconciled with the neoclassical growth framework. The destruction of productive capacities by the war implied a temporary deviation from the steady state growth path, and a part of the "growth miracle" of those countries in the fifties is simply convergence to the steady state. However, neoclassical growth cannot be the sole explanation for the extraordinary productivity growth performance in the OECD countries during the post-war period. This can be seen from a usual growth accounting exercise which leaves a large residual not explained by conventional factor inputs: while capital-deepening can explain some of the observed output growth, employment (in persons) is fairly stable, and the working time reduced significantly.[20] Some part of the resulting total factor productivity growth may be accounted for by quality changes of physical capital and the increase of human capital during that period, but another part is probably due to scale economies and knowledge spillovers.

Scale economies and knowledge spillovers fit almost perfectly into the picture of loosing leadership of the United States' economy during the last 30 years. During that period, markets and business have become more global and national technology due to geographical proximity ceased to be important. A large market of industrial products also emerged in Europe, and the increasing international trade implied that "... efficient companies producing attractive products increasingly faced a world market rather than a national

[17] Another view is that problems within the United States are responsible for the catching-up of the follower countries. For a discussion, see Nelson, Wright (1992).

[18] See Dumke (1991) and Dowrick, Nguyen (1989).

[19] See Krengel (1958).

[20] For instance, average output growth in Germany amounted to slightly above 3 percent per year in the 1960-1990 period. Capital-deepening accounted for about 1.3 percentage points, but taking into account the working time reduction of about one percent per year leaves a total factor productivity growth of about 2.5 percent, i.e. most of the growth is left unexplained. See Smolny (1995).

market."[21] In addition, trade in natural resources expanded and countries became less dependent on local materials. This development was accompanied by a large increase of foreign direct investment as e.g. European branches of United States' firms. Protectionism became less practicable than before, and best practice technology became available for everybody. Of course, this discussion is also relevant for the United States' productivity performance, since markets grew also for U.S. firms, and knowledge spillovers are also important within the U.S..[22]

However, the discussion on knowledge spillovers and convergence of technology is not as simple as these arguments suggest. First, at the beginning of the nineties, the United States is still the most productive economy at the aggregate level by standard methods of measurement. This means that there may have been some catching-up, but it is difficult to perceive whether (unconditional) convergence will eventually occur. For instance, one hypothesis may be that knowledge spillovers lead to a convergence in productivity growth rates, but differences in the steady state productivity levels persist due to e.g. different levels of human capital or physical/R&D investments. This has some resemblance to the neoclassical growth model, and renders the empirical analysis difficult.

Second, the quantitative impact of knowledge differences is probably related to other variables. For instance, Cohen, Levinthal (1989) emphasize the importance of own R&D activities for learning. Since R&D often requires physical investment and human capital, this strengthens the case of convergence for those firms which engage in this process, while convergence will not occur for other firms. In a related hypothesis, Abramovitz (1986) emphasized the importance of the institutional and organizational structure of the followers and coins the term of the "social capability" to absorb more advanced technologies. Another argument which has been developed in a series of papers[23] focuses on the relation between productivity spillovers and the openness of the country, e.g. the extent of international trade and foreign direct investment.

Therefore, one cannot derive a clearcut theoretical result whether spillovers are strongest when productivity differences are very large, or contrary, spillovers are stronger when productivity differences are rather small. The opportunity for catching-up is higher in the one case, but the capability to catch up is higher in the other case.

2.2 Sectoral productivity convergence

The empirical analysis in the next sections focuses on the different sources, transmission channels, and effects of sectoral productivity spillovers. First, it is tested for an impact of the productivity gap between a sector in Germany

[21] Nelson, Wright (1992), p. 1957.

[22] See e.g. Barro, Sala-i-Martin (1991,1992), Caballero, Lyons (1992), and Carlino, Mills (1993).

[23] For a recent overview see Coe, Helpman (1995).

and its U.S. counterpart on German productivity growth. This corresponds to a general specification of catching-up and is performed by an augmented non-structural stationarity analysis of the productivity gaps.

Second, it is tested to what extent the catching-up can be attributed to neoclassical sources, i.e. a different development of factor inputs or different rates of exogenous technical progress, and to what extent it is based on knowledge spillovers. This distinction is important, because knowledge spillovers indicate inefficiencies of a decentralized market system and scale economies at a more aggregate (world) level. Therefore, they imply a source of endogenous growth not only for the less developed country but also for the productivity leader.[24] Of course, the hypotheses of neoclassical convergence and knowledge spillovers are not exclusive but may be combined: for instance, neoclassical convergence is promoted if the capital-intensive technique is already developed. Then it can be bought, and substitution is possible by choice on the market, as opposed to the more difficult and longer-lasting substitution by developing a new technique.[25] The analysis is carried out within a structural theoretical model based on a production function framework. In order to isolate the influence of knowledge spillovers, it is controlled for factor input developments and common business cycle fluctuations.

Third, beside the test for an impact of the productivity gap, it is tested for an impact of the growth of the leader country's productivity on the follower country's productivity performance, i.e. intra-industry spillovers. This need not lead to convergence, but it may be a source of endogenous productivity growth even after productivity levels have converged.

Fourth, within the structural model it is also tested for productivity spillovers between different sectors within both countries, i.e. inter-industry spillovers in Germany and the U.S..[26] From the theoretical arguments, the basic level for the analysis of knowledge spillovers should be the level of the individual firm. Firms invest in R&D and develop new techniques and products which affect not only their own productivity but may and will also be used by other firms. Those other firms may be located within the sector and within the country (region), within the sector but in another country, or in another sector but within the country. The first kind of spillover can only be analyzed with micro data of individual firms (and is left for future work), but the available data-set of sectoral data for two countries allows to test for cross-county (intrasectoral) and cross-sectoral (inter-industry) spillovers.

Therefore, the analysis here stands in between an aggregate model of cross-country convergence, as analyzed by many other authors,[27] and the few studies on R&D spillovers with, in most cases, rather short data panels for individual

[24]Therefore, knowledge spillover can also be an explanation for United States' growth.

[25]In addition, knowledge spillovers are probably promoted by own R&D investment, physical investment, human capital, etc..

[26]A more detailed analysis of total factor productivity spillovers between German sectors is contained in Smolny (1995).

[27]See Levine, Renelt (1992) for an overview.

firms.[28] The idea is to identify scale economies and spillovers through their effects on the catching-up of German industry sector productivity with respect to their United States counterparts. Spillovers and scale economies deserve a prominent role in endogenous growth models, because they indicate an inefficiency of a decentralized market system and therefore, may have important implications for economic policy recommendations.

The analysis of productivity growth and convergence is complemented by testing for further effects from the existence of a high productivity foreign leader sector on the development of the domestic sector. This is carried out by estimating the impact of the productivity gap on different German sectoral variables within a non-structural, reduced form estimation. First, it is tested for an impact of the technological distance on the capital-labour ratio to obtain a more detailed picture of the importance of neoclassical convergence via capital-deepening. Second, it is tested for an impact on sectoral growth, i.e. investment, output, and employment. In case of knowledge spillovers, firms have additional incentives to invest. In addition, new products and cost reductions due to productivity advances allow for larger market shares of sectoral products via substitution effects on the domestic market. On the other hand, market penetration of technologically more advanced foreign firms may result in lower growth and a concentration on low tech activities. The existence of a productivity gap has probably also an effect on domestic sectoral prices. In case of knowledge spillovers, the higher productivity growth of those sectors allows for lower prices, and even without spillovers, the import penetration from the higher developed countries may have a dampening effect on prices.

Summarizing, it is tried to establish the link between productivity differences and the growth in the country being behind.[29] The emphasis is both on the identification of the sources, i.e. neoclassical substitution versus knowledge spillovers, and of the effects of being behind.

2.3 Estimation strategy

The data base consists of a panel with sectoral data for Germany and the United States from 1960–1990. For the empirical analysis, labour productivity is chosen as the main endogenous variable instead of total factor productivity, because the calculation of the latter would rely more on possibly poorly measured data of the capital stock. The first statistical test for sectoral productivity convergence is based on an implication of the model: labour productivity (total factor productivity) is seen as a non-stationary variable. Convergence, however, implies that the gap between productivity levels of different countries should become smaller, i.e. sectoral productivity ratios should be stationary. In case of a correct measurement of productivity, the mean of the ratio should become equal to one. In case of measurement errors (or to test for a constant

[28] For instance, Bernstein, Nadiri (1986) and Nadiri (1993). Inter-industry spillovers are analyzed by Levin, Reiss (1988) on the base of R&D data.

[29] See Dollar, Wolff (1988).

but non-zero productivity gap), a constant should be included in the test. In addition, the lagged endogenous variable is included to handle autocorrelation, and it is tested for trend-stationarity.

$$\Delta yl_t^d = \text{constant} + \text{trend} + \lambda \cdot yl_{t-1}^d + \gamma \cdot \Delta yl_{t-1}^d \tag{1}$$

YL^d : relative productivity, Germany vs. U.S.

Small case letters denote logarithms of the respective variable. The sector index is suppressed. The data panel allows to perform the tests for different sub-samples of the data. First, stationarity tests are carried out for each sector separately. The limitation of this approach is the low power of stationarity tests within small samples which often leads to inconclusive results. Alternatively, the data are pooled. This increases the statistical power of the tests, but does not allow to discriminate between (non)-stationarity for sector groups or sub-periods. Therefore, the stationarity tests are also performed for sub-periods, i.e. ten-year intervalls,[30] and for the sub-sample of more homogeneous manufacturing sectors.

A second approach to sectoral productivity spillovers and convergence is to test for an impact of the productivity gap on the productivity growth rate in the follower country. This represents more of a structural approach. Different productivity levels in the countries should cause higher productivity increases in the follower country via capital-deepening and technology transfers. In addition, it is controlled for business cycle-induced variations of factor utilization. The underutilization of labour during the business cycle implies a procyclical labour productivity, and common sectoral business cycle fluctuations could result in short-run correlation of labour productivities which should be distinguished from long-run causation.[31] The robustness of the results is tested with additional versions allowing for the lagged endogenous variable, sectoral dummies, and alternatively a trend or time dummies:

$$\Delta yl_t^g = \text{constant } (+ \text{ trend}) + \text{TD} + \text{SD} + \lambda \cdot yl_{t-1}^d + \gamma \cdot \Delta yl_{t-1}^g + \alpha \cdot \Delta u_t \tag{2}$$

YL^g : labour productivity, Germany
U : factor utilization
SD : sectoral dummies
TD : time dummies

Sectoral dummies capture both sector-specific growth effects and allow for stationary productivity gaps between the sectors. The equation is again estimated for different sub-samples of the data.

However, statistical stationarity analysis represents only a first step for the analysis of sectoral spillovers and convergence. The power of stationarity

[30] An alternative sample split would be in 1974/75, i.e. the years of the oil price shock and the trend break in world trade. However, a prior data inspection revealed a more important trend break at the beginning of the eighties. See also figure 1.

[31] See Flaig, Steiner (1993) for the importance to control for business cycle effects.

tests within small samples is limited, and an additional problem here is that the "equilibrium", i.e. the completed convergence, is not achieved within the sample: at the end of the observation period in 1989/90, the United States is still the more productive country in most sectors. Therefore, the non-structural stationarity analysis is complemented with the estimation of a structural model based on a production function.[32] The starting point is a production function with labour, physical capital, human capital, and knowledge as inputs:

$$Y = Y(K, L, HK, U, K^n) \tag{3}$$

Y :	real output
K :	physical capital stock
L :	employment
HK :	human capital per worker
K^n :	knowledge

The business cycle indicator controls for a changing utilization of the inputs. This represents the basic neoclassical approach, augmented with human capital, and (endogenous) knowledge.[33] Assuming linear homogeneity in the standard production factors physical capital and labour, and rewriting eq. (3) in logarithmic differences leads to:

$$\Delta yl_t = \Delta yl(\Delta kl_t, \Delta hk_t, \Delta u_t, \Delta k_t^n) \tag{4}$$

KL : capital-labour ratio

Small case letters again denote logarithms of the respective variable. Knowledge is specified by introducing the concept of a knowledge production function.[34] The first determinant of knowledge changes is the technological gap between the leader and the follower country's sector. This approach already allows to distinguish productivity convergence via knowledge spillovers from neoclassical capital-deepening effects, since it is controlled for the impact of changes of the domestic capital-labour ratio. A second argument of the knowledge production function are productivity changes abroad. Technical progress also takes place in the leader country, and the dynamic process of technology transfer may result in a faster spillover of recent technological developments.[35] Third, it is tested for inter-sectoral spillovers within each country. Knowledge advances in one sector should be affected by knowledge increases in other sectors. This argument is specified by allowing for an impact of other sectors' productivity growth:[36]

$$\Delta k_t^n = \Delta k^n(yl_{t-1}^d, \Delta yl_t^o, \Delta yl_t^u) \tag{5}$$

[32] A similar framework is used in Smolny (1995) for the analysis of inter-sectoral spillovers between German sectors.

[33] A similar approach is used in most studies on cross-country growth convergence, see e.g. Barro (1991).

[34] See Nadiri (1993).

[35] This specification refers to the distinction between conditional convergence and spillovers.

[36] A specification with other sectors' total factor productivity growth yield the same qualitative results.

YL^o : labour productivity of the other sectors
YL^u : sectoral labour productivity, United States

In addition, it is tested for other arguments from endogenous growth models: knowledge increases may also depend on own and others' gross investment (learning by doing, embodied technical progress), the level of human capital (as a necessary input to the knowledge production process), and the level of the business cycle situation. This corresponds to a test on scale economies at the sectoral level.[37] Inserting eq. (5) into eq. (4) results in:

$$\Delta yl_t^g = \Delta yl^g(\Delta kl_t, \Delta hk_t, \Delta u_t, yl_{t-1}^d, \Delta yl_t^o, \Delta yl_t^u) \qquad (6)$$

A linearized version of eq. (6) is the base for the empirical estimation in the next section. Again the equation is estimated for different sub-samples of the data, and it is controlled for measurement errors, exogenous technical progress, and sectoral/time specifica with a constant, sectoral dummies, and alternatively a time trend or time dummies.

Finally, it is tested for additional effects from being behind. A general, non-structural reduced form model is estimated to test for effects of the productivity gap on the capital-labour ratio kl, the capital stock k, output y, employment l, and prices p. Estimating the capital-labour ratio on the productivity gap gives a second view of the importance of (neoclassical) capital-deepening for the catching-up. The other equations yield an estimate of the effects of the catching-up process on growth and prices of the sector being behind. The change of the corresponding sectoral variable is regressed on the productivity gap:

$$\Delta x_t = \text{constant} + \text{TD} + \lambda \cdot yl_{t-1}^d + \alpha \cdot \Delta u_{t,i} + \gamma_1 \cdot \Delta x_{t-1} + \gamma_2 \cdot \Delta x_{t-2} \qquad (7)$$

$x \in \{kl, k, y, l, p\}$. The equation is again estimated for different sub-samples of the data, and a constant, time dummies, the business cycle indicator, and lags of the endogenous variable are included.

[37] Since no sectoral data on R&D were available, the test for the impact of R&D on productivity growth is left for future work.

3 Empirical analysis

3.1 Data and empirical specification

The main data base for the empirical investigation are the OECD International Sectoral Statistics.[38] It includes annual data for employment and wages, as well as data on value added, investment, and the capital stock[39] at comparable international prices for 26 sectors from 1960–1990.[40] First, some cross-country measures of the data are reported. In figure 1, the relative (to the U.S.) labour productivity levels for the main OECD countries are depicted.[41] Labour productivity is value added per employee, and the productivity comparison is based on aggregate purchasing power parities, i.e. 1985 international prices. From the upper figure one can see the productivity lead of the United States at the beginning of the sixties which then reduced smoothly until the end of the eighties. Germany had achieved the level of the other European countries already in 1960 (or before). The productivity level for Germany "converged" from less than 50 percent of the United States' level in 1960 to more than 80 percent in 1989.

The aggregate data are comparable to those from the Penn World Tables from Summers, Heston (1991). However, the available data set allows a more appropriate definition of productivity, since data on employment instead of measures of population are available. In addition, the public sector is excluded which gives a more appropriate measure of value added and the capital stock.[42] It is also possible to exclude mining, i.e. the exploitation of natural resources. Therefore, compared with the estimation of cross-country growth regressions, as performed by many other authors, the available data set exhibits a greater degree of homogeneity with respect to measurement. On the other hand, the sectoral data still exhibit a large and meaningful cross-sectional variation. This can be seen already in the lower part of figure 1, where the relative productivity for the manufacturing sector is depicted. Here the picture of convergence is less clear. The available data may give some impression of (unconditional) convergence until the end of the seventies, but the changing trends in the seventies and eighties (at different time period for the 6 countries) leave quite a different picture.

[38]See OECD (1993) and Meyer-zu-Schlochtern, Meyer-zu-Schlochtern (1994).

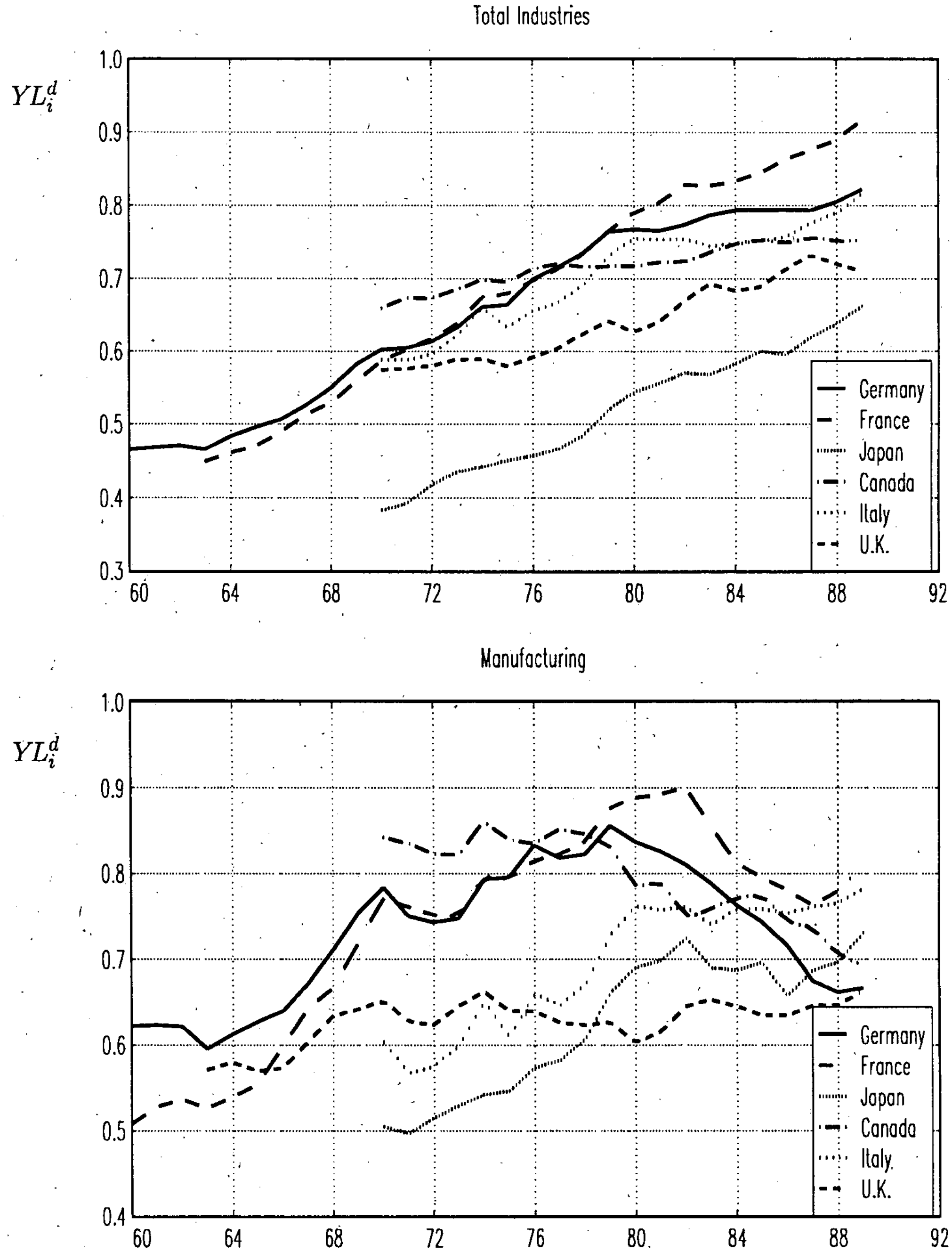
[39]The capital stock is taken from the beginning of the year which implies a time-to-build assumption. For some sectors and time periods, the capital stock data are calculated from gross investment and constant depreciation rates, partly data are taken from German national accounts.

[40]The sector list is depicted in table 4 in the appendix.

[41]The reported length of the time series is dictated by the availability of sectoral data in the OECD data base. While data for Germany and the United States start 1960, for the other countries shorter time periods are available.

[42]The measurement of value added in the public sector is very poor. Equally important is the measurement of the capital stock which may or may not include parts of infrastructure capital.

Figure 1: Relative labour productivity, country i vs. the U.S.



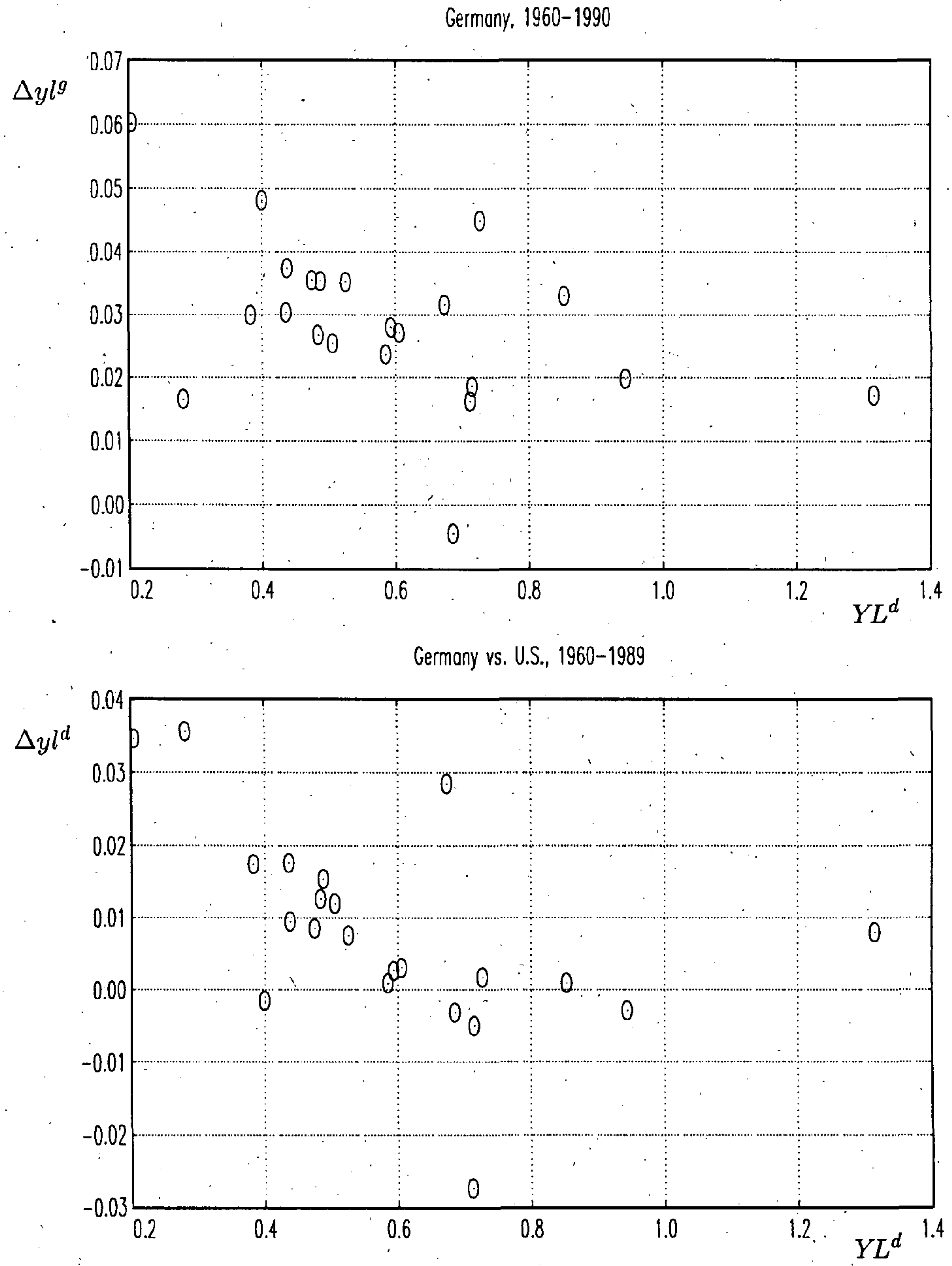
YL_i^d: Relative labour productivity, country i vs. the U.S.
Source: OECD (1993)

The sectoral differences of the process of convergence of German industries versus their United States' counterparts are also the theme of the next figures. In the upper half of figure 2, the average annual labour productivity growth of the individual sectors in Germany from 1961-90 is plotted against the productivity gap with respect to the United States in 1960.[43] Below, the *relative* labour productivity growth is depicted. The restriction to the sample from 1960-90 is caused mainly by data availability, but has the advantage of a rather homogeneous institutional environment. In Germany, for instance, at the end of the fifties the Saarland joined the FRG,[44] and the opening of the Wall and the unification of East and West Germany in 1989/90 meant another change of the borders. For this figure and for the empirical analysis below, the public sector, mining, and real estate are excluded: the public sector is excluded because of the poor quality of real value added data, productivity differences in mining are probably mainly due to the different availability of natural resources, and real estate (especially private housing) is treated differently in German national accounts as compared to the United States. One may also argue that agriculture and/or some part of services should be excluded for the same reasons (regulation, measurement, natural resources), therefore all equations are also estimated for the more homogeneous manufacturing sectors.[45]

From the figures, it can be seen that the sectoral variance of both productivity growth rates and productivity gaps is enormous, i.e. some sectors grow remarkably faster than other, (absolute and relative,) and for some sectors, the gaps are much larger than for others. For instance, productivity in German agriculture was only 20 percent of the United States' level in 1960 and grew with about 6 percent per year until 1990; this is 3.5 percent more than in the United States. At the other end of the scale, productivity in German community, social, and personnel services was about one third higher than in the United States. The figures also reveal a general picture of (unconditional sectoral) convergence: a higher productivity gap is associated with a larger (relative) productivity growth in Germany. However, one should be careful in drawing too strong conclusions from these data. The productivity comparison is based on real values at 1985 international prices, but only for the aggregate. No sectoral international prices were available. Therefore, unambiguous results about the significance of productivity convergence can only be achieved from an econometric analysis. Regressions allow to exploit all information in the data. The time-series/cross-section data set extends the number of observations and increases the variation, and thereby allows for a more rigorous empirical testing. For instance, it allows to correct for possible measurement errors due to sectoral different international prices by inclusion of sectoral dummy variables.

[43]The data with the sector classification are contained in table 5 in the appendix.
[44]In addition, German reconstruction was mainly completed.
[45]The results are not reported in detail, but are available on request from the author.

Figure 2: Sectoral productivity convergence



YL^d: Relative sectoral labour productivity, 1960
Δyl^g: Labour productivity growth, Germany
Δyl^d: Relative labour productivity growth, Germany vs. U.S.

In figure 3, some time series measures of the data are shown. The upper figure depicts the average relative productivity of the German sectors together with its cross-sectoral standard deviation (std). The sectoral variance is enormous, and it does not decline. Therefore, one has to conclude that the observed process of convergence was different from a simple achievement of best practice technology in the two countries. In the lower figure, the average productivity growth rate is depicted together with its cross-sectoral standard deviation. The general characterization of these series is the declining growth trend (from about 5 percent in the sixties to about 2 percent in the eighties), the procyclical development of labour productivity which hints towards a (common) changing utilization of the factors, and again the high cross-sectoral variance.

For the regression analysis, the OECD data were augmented with German business cycle data to control for a changing utilization of the factors. The data for Germany are taken from the business survey of the ifo-institute.[46] For the empirical investigation, the business cycle indicator u is measured as the difference of the shares of firms reporting a good and a bad business cycle situation, respectively.[47] Because no comparable sectoral data were available for the United States, aggregate data on capital utilization and the working time are taken from the OECD Main Economic Indicators.

Some remarks are necessary with respect to the construction of an index of sectoral human capital. The human capital per employee may be measured by the real cost of obtaining it, for instance approximated by the years of schooling and formal apprenticeship training. However, this measure does not take into account those qualifications which are acquired by informal training and experience. In addition, these data were not available at the sectoral level. Another indicator for human capital can be constructed from its returns. The average wage paid in a sector, in relation to the wage for unqualified work, can be used as a measure for the quality of its work force. Why should higher wages be paid in a sector, if not for better qualified work? This procedure has some resemblance to the calculation of the real capital input. Nominal market values are deflated by an appropriate price index.[48]

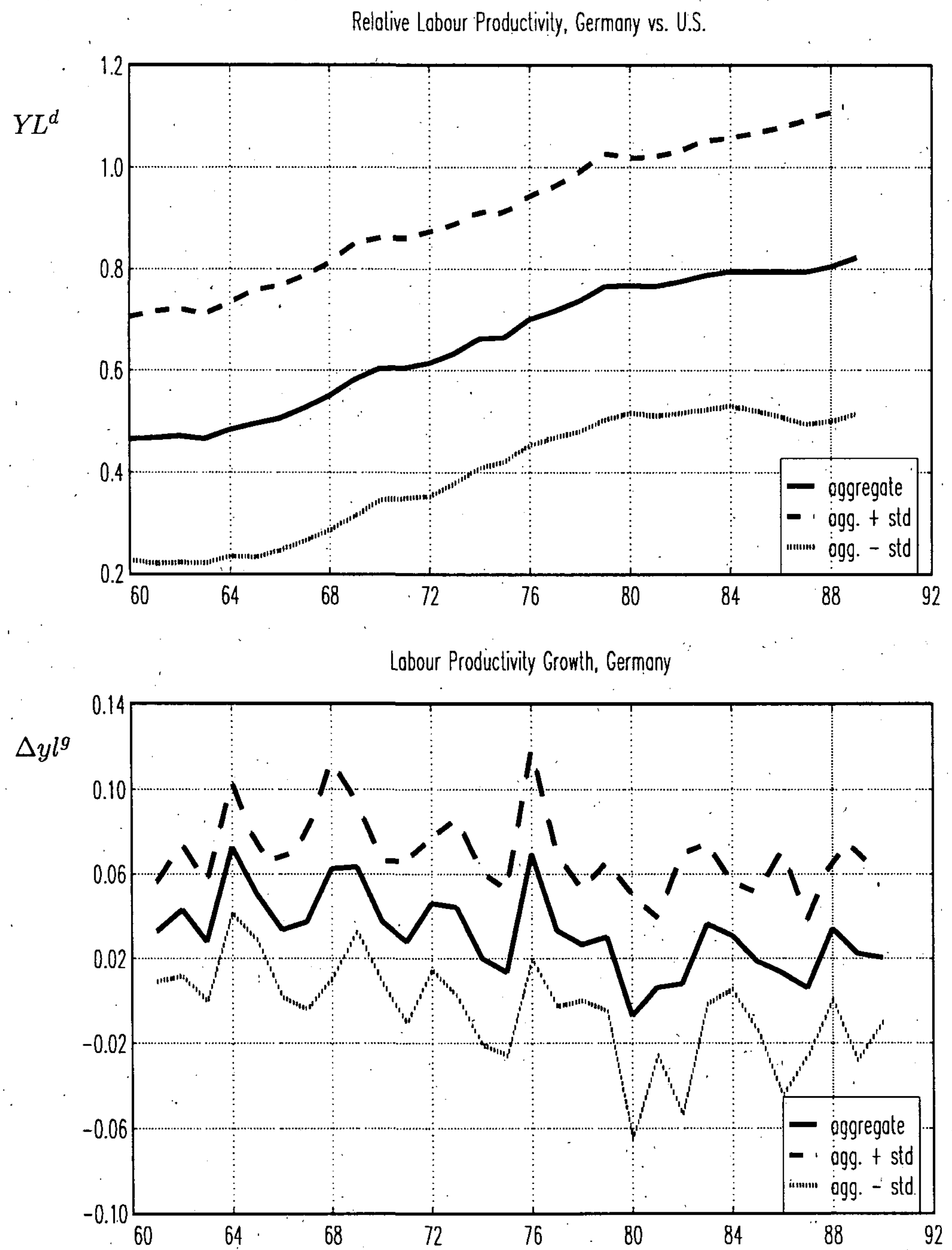
Here, a two-step procedure is applied to capture this argument. First, the average sectoral wage is set in relation to the average aggregate wage. This gives a measure of the relative qualification of the worker for the sectors. Second, an indicator for aggregate human capital is calculated as the ratio of the average aggregate wage and the wage for unqualified work. For both

[46] Special thanks are due to the ifo-institute for providing me with those data. These data are available only for the industry sectors and from 1961 or 1967 onwards. The values for aggregate industry were also used to approximate the business cycle effects for the other sectors which may be excusable in view of their high sectoral correlation.

[47] Different business cycle indicators from the ifo-data were tested, but the results were inferior to those presented below.

[48] A similar procedure is proposed in a recent working paper by Mulligan, Xala-i-Martin (1995) with U.S. regional data. The authors also give an elaborate discussion of the issue.

Figure 3: Relative labour productivity, labour productivity growth



ratios, comparable data were available.[49] Of course, one can argue that sectoral wages are also determined by other factors than human capital; and there is a large literature on inter-industry wage differentials. However, one result of this literature is that a substantial part of inter-industry wage differentials can be attributed to observable, human capital related characteristics of the work force.[50] In addition, the remaining differences are mainly attributed to efficiency wage arguments.[51] This is consistent with the interpretation that wage differentials can serve as an indicator of the quality of the work force.[52]

3.2 Estimation results

The basic endogenous variable for the analysis of convergence is the sectoral productivity gap between the United States and Germany. Table 7 in the appendix contains sectoral results about the stationarity of the gap and the corresponding productivity growth rates.[53] The first columns contain the coefficients and t-statistics of augmented Dickey/Fuller-tests (with a constant and one lag)[54] for the productivity growth rates for each sector in both countries.[55] The general conclusion that can be drawn from this test is that productivity growth rates are stationary, i.e. non-stationarity can be rejected for nearly all sectors in both countries. The next columns contain the corresponding results for the productivity gap. Here, the conclusion is that non-stationarity cannot be rejected for nearly all of the sectors. This results hold also for the test on trend stationarity in the last columns. This result is not very surprising and points towards the low power of stationarity tests in small samples, especially in the case here, where the equilibrium is not achieved within the sample in most sectors.

An increase in statistical power can be achieved with pooling of the data. The theoretical work on stationarity in panel data is still preliminary, but the first results indicate strong increases in efficiency. In addition, with panel data, the distribution of the test-statistic becomes more close to a normal distribution

[49] The definition of unqualified work may have changed during the time period under consideration. Therefore the wage for unqualified work was alternatively substituted by the wage of a rather homogeneous group, i.e. blue collar workers with completed vocational training. In addition, it was tested whether the human capital can be approximated by the share of workers in the high qualification groups.

[50] See, for instance, Krueger, Summers (1988) and Katz, Summers (1989). Wagner (1991) reports results for Germany.

[51] See again Krueger, Summers (1988). These authors also mention union density as anther cause of inter-industry wage differentials which, however, hardly plays a role for Germany.

[52] It should be noted that the usage of the term human capital here is more comprehensive than that of the standard Becker/Mincer human capital model. It captures all aspects of the quality of the work force, i.e. it includes for instance also workers' effort and unobserved ability.

[53] Table 5 in the appendix contains additional sectoral data about productivity gaps and productivity growth.

[54] One lag was sufficient to handle autocorrelation of the residuals.

[55] The sector classification is contained in table 4 in the appendix.

than to the usual Dickey/Fuller distribution:[56] In a pure cross-section analysis, the coefficient of the productivity gap would follow a Normal distribution; a pure time-series investigation would yield a Dickey/Fuller distribution; with pooled data the distribution is between these extremes. The lower part of table 7 contains the results of stationarity tests with the pooled data. Now the productivity gaps appear stationary for the full sample and for the first two ten-year intervals. The strongest results in favour of stationarity are achieved for the seventies. The results for the smaller sample of manufacturing sectors in the last rows show no remarkable difference: convergence coefficients are slightly higher, but also slightly less significant.

More conclusive results can be achieved by putting more structure into the empirical testing. From theoretical arguments, it is expected that the main driving force of the adjustment process is the catching-up of the technologically less developed sector. In addition, the long-run adjustment of technology is interferred with short-run, business cycle induced variations of labour productivity. Table 1 contains the results of an augmented stationarity analysis of productivity gaps. The endogenous variable is the German productivity growth rate, i.e. the expected theoretical structure is imposed on the data. Again, the data are pooled, and results for sub-periods are reported. In the first rows, the lagged productivity gap is the only explanatory variable. The results correspond to the stationarity tests before. In the next rows, the equation is augmented with the German business cycle indicator and the lagged endogenous variable. The business cycle indicator is highly significant, and an increase of efficiency is indicated by the higher t-statistics of the productivity gap. The lagged endogenous variable is important only in the sixties. Nevertheless, the basic results for convergence remain nearly unchanged. Catching-up and convergence was important in the sixties and seventies; for the eighties, the productivity gap has no explanatory power for German productivity growth.[57] The estimated convergence is about two percent per year, i.e. lower than predicted by the neoclassical model. These results are robust with respect to including a time trend.[58] The coefficients remain nearly unchanged, the trend is only important in the seventies. Adding sectoral dummies leads to an increase of the adjustment coefficient, but the results became unstable for sub-periods. Including sectoral dummies *and* alternatively a time trend or time dummies reduced the significance of the impact of the productivity gap.

More detailed results on the relative importance of capital-deepening and knowledge spillovers for the catching-up can be achieved by putting more struc-

[56] See Levin, Lin (1993), Quah (1994), and Bernard, Jones (1995).

[57] Additional (not reported) estimates with the relative growth rate as the endogenous variable yield the same qualitative results, with significant catching-up only in the sixties and seventies (or for the whole sample). One remarkable result is that the constant and the trend are significant only for the sixties. Similar results were achieved for the manufacturing sector: catching-up was most important in the seventies; the convergence coefficent is slightly higher, but less significant. Similar results are reported by van Ark, Pilat (1993).

[58] The trend always starts in 1960.

Table 1: Tests for convergence

endogenous variable: Δyl^g_t

smpl	const.	yl^d_{t-1}	Δu^g_t	trend	Δyl^g_{t-1}	SD	TD	$\overline{R}^2$	SEE
1961-90	0.018	−0.025				N	N	0.044	0.043
	(7.15)	(-5.62)							
1961-70	0.035	−0.013				N	N	0.016	0.037
	(8.17)	(-2.13)							
1971-80	0.015	−0.035				N	N	0.059	0.045
	(3.32)	(-3.83)							
1981-90	0.012	−0.010				N	N	0.001	0.042
	(3.01)	(-1.05)							
1961-90	0.015	−0.026	0.073		0.087	N	N	0.206	0.040
	(5.79)	(-6.02)	(10.69)		(2.40)				
1961-70	0.028	−0.017	0.074		0.161	N	N	0.328	0.032
	(5.73)	(-2.94)	(8.46)		(2.59)				
1971-80	0.016	−0.035	0.090		0.061	N	N	0.278	0.040
	(3.62)	(-4.27)	(8.09)		(0.91)				
1981-90	0.011	−0.009	0.071		−0.107	N	N	0.078	0.040
	(2.73)	(-1.02)	(4.43)		(-1.76)				
1961-90	0.046	−0.019	0.082	−0.002	0.027	N	N	0.272	0.038
	(9.52)	(-4.38)	(12.37)	(-7.48)	(0.77)				
1961-70	0.030	−0.017	0.074	−0.000	0.165	N	N	0.324	0.033
	(3.53)	(-2.88)	(8.28)	(-0.25)	(2.55)				
1971-80	0.101	−0.029	0.107	−0.005	0.073	N	N	0.360	0.038
	(6.07)	(-3.71)	(9.73)	(-5.27)	(1.15)				
1981-90	0.034	−0.010	0.076	−0.001	−0.103	N	N	0.077	0.040
	(1.26)	(-1.11)	(4.45)	(-0.86)	(-1.69)				
1961-90		−0.051				Y	N	0.103	0.041
		(-5.78)							
1961-90		−0.058	0.074		0.012	Y	N	0.272	0.038
		(-6.69)	(11.33)		(0.34)				
1961-90		−0.022	0.083	−0.002	−0.055	Y	N	0.328	0.037
		(-2.24)	(12.98)	(7.03)	(-1.51)				
1961-90		−0.021	0.096		−0.064	Y	Y	0.375	0.035
		(-2.03)	(7.98)		(-1.61)				
1961-90		−0.019	0.094		−0.041	N	Y	0.315	0.037
		(-4.39)	(7.50)		(-1.03)				

$t-$values in parantheses
Sample: All industry sectors excluding mining and real estate
SD: sectoral dummies, TD: time dummies
u: business cycle indicator, trend: time trend starting in 1960

ture into the empirical equation. Table 2 contains the results of the estimation of the model based on an augmented production function. For comparison, the first line contains again the results of an augmented stationarity test.[59] In the second row, the results of the estimation of a Solow model with constant return of scale and exogenous technical progress are reported. The results, rather surprisingly, yield a quite reasonable estimate for the elasticity of output with respect to capital: the estimated coefficient is close to the share of capital (or residual) income in value added. This gives an impression about the advantages of cross-sectoral data as compared with a pure time-series analysis, where the effect of the trend increase of the capital-labour ratio often cannot be distinguished statistically from simple deterministic or stochastic time trends. It shows also the relative advantage against a cross-country growth analysis, where the capital intensity is correlated with many other determinants of growth, and stands more or less for the general state of development of the country. The coefficient associated with the business cycle indicator is again highly significant which points towards the importance to control for underutilizations of labour and capital for the analysis of long-run growth. Omitting that variable yielded a less significant and lower coefficient of the capital-labour ratio (not reported). From the regression summary statistics, it can be seen that the productivity gap with respect to the United States has about the same explanatory power for labour productivity changes as the capital-labour ratio which points towards the importance of catching-up for German growth.

The next row includes the results of the combined model, and both, the capital-labour ratio and the productivity gap are significant. This already implies that catching-up is also due to other factors than neoclassical capital-deepening: it is controlled for capital-deepening, and the productivity gap contributes still to the explanation of German productivity growth. However, the coefficient is lower than in version (1) which implies that capital-deepening is part of the catching-up process. In addition, the constant is reduced which means that a larger part of growth is explained endogenously.

In the fourth row, the human capital indicator is included as an additional explanatory variable. In the estimates, only the relative sectoral change of human capital, measured by relative wages, proved significant. Any attempts to estimate an effect of aggregate human capital yielded insignificant results. This may be due to the low variation of this series, its development is close to a simple trend, and the variable is dropped for the reported results. However, the relative human capital contributes significantly to the explanation of productivity growth. This is in accordance with growth models that place a strong emphasis on human capital. It should be noted that the relative wage does not stand for substitution effects. These are captured by the capital-labour ratio, and the coefficent still remains significant and nearly unchanged. Therefore, the results also indicate the appropriateness of approximating relative human

[59] The insignificant lagged endogenous variable is dropped from the equation.

Table 2: Sources of productivity growth, Germany

endogenous variable: Δyl_t

	const.	trend	Δkl_t	Δhc_t	Δu_t	Δyl_t^o	yl_{t-1}^d	Δyl_{t-1}^u	$\overline{R}^2$	SEE
convergence										
(1)	0.047	−0.002			0.083		−0.019		0.272	0.038
	(10.46)	(-7.85)			(12.44)		(-4.44)			
(2)	0.041	−0.001	0.254		0.092				0.277	0.038
	(8.10)	(-6.24)	(4.88)		(13.49)					
(3)	0.033	−0.001	0.226		0.091		−0.016		0.293	0.038
	(6.06)	(-5.56)	(4.33)		(13.32)		(-3.83)			
(4)	0.037	−0.001	0.214	0.523	0.086		−0.017		0.368	0.036
	(6.55)	(-6.32)	(4.18)	(6.85)	(12.77)		(-3.91)			
spillovers										
(5)	0.018	−0.001	0.217	0.529	0.070	0.311	−0.016		0.375	0.036
	(2.04)	(-2.95)	(4.26)	(6.97)	(7.90)	(2.78)	(-3.86)			
(6)	0.017	−0.001	0.225	0.532	0.070	0.289	−0.015	0.060	0.378	0.035
	(2.00)	(-2.97)	(4.42)	(7.02)	(7.95)	(2.58)	(-3.58)	(1.96)		
(7)	−0.007		0.273	0.539	0.058	0.508	−0.017	0.060	0.370	0.036
	(-2.06)		(5.61)	(7.07)	(7.37)	(5.95)	(-4.06)	(1.93)		
dummy models										
(8)			0.198	0.556	0.053	0.550	−0.021	0.034	0.397	0.035
			(3.63)	(7.31)	(6.63)	(6.11)	(-2.20)	(1.03)		
(9)		−0.001	0.146	0.554	0.064	0.351	−0.011	0.039	0.406	0.035
		(-3.07)	(2.57)	(7.33)	(7.36)	(3.17)	(-1.17)	(1.16)		
(10)			0.228	0.481	0.082		−0.015	0.069	0.398	0.035
			(4.04)	(6.16)	(6.76)		(-3.49)	(2.09)		
for sub-periods										
(11)	0.015	0.001	0.085	0.458	0.072	0.170	−0.008	0.167	0.426	0.029
	(1.06)	(1.43)	(1.20)	(3.47)	(5.32)	(0.79)	(-1.29)	(2.19)		
(12)	0.036	−0.002	0.290	0.496	0.083	0.233	−0.031	0.130	0.446	0.035
	(1.39)	(-1.89)	(3.10)	(4.28)	(5.94)	(1.42)	(-4.29)	(2.38)		
(13)	−0.037	0.002	0.459	0.651	0.078	−0.369	−0.013	−0.001	0.204	0.038
	(-1.27)	(1.46)	(4.04)	(4.58)	(3.53)	(-1.22)	(-1.59)	(-0.01)		
a model for the U.S.										
(14)	0.005		0.136	0.420	0.591*	0.621		0.107	0.167	0.044
	(1.85)		(2.82)	(3.69)	(2.05)	(4.32)		(2.70)		
					0.060					
					(0.80)					

t-values in parantheses

Sample: 1960-90, all industry sectors excluding mining and real estate.

(8)+(9) include sectoral dummies, (10) includes time dummies

(11): sample 1961-70, (12): sample 1971-80, (13): sample 1981-90

Δkl: log change of capital-labour ratio

Δhc: log change of human capital indicator

Δyl^o: log change of other sectors' productivity

* Coefficient of aggregate hours

capital with its returns, i.e. relative wages.

In the fifth row, it is also tested for an impact of other (German) sectors' productivity growth which stands for inter-sectoral spillovers. The results indicate a rather strong impact on sectoral productivity changes. The estimated coefficient is significant, and its value implies a rather strong association of the variables. In addition, the constant is reduced by about one half. This result, first of all, is consistent with inter-sectoral spillovers, strong enough to account for endogenous growth. Second, it cannot be attributed simply to a simultaneous equation bias: the variable is calculated excluding the sector under consideration. However, it cannot be proven that it is caused by knowledge spillovers. For instance, the correlation may also be caused by common, unobserved business cycle effects. It is tried to control for them in the equation with different business cycle indicators, but something may be left. Another explanation would be an exogenous increase of knowledge which is important in most or all of the sectors. The sectoral specification allows to look for inter-sectoral correlation of productivity enhancements which may indicate spillovers. It does not allow to discriminate between common productivity shocks and causation between sectoral productivity developments and other sectors' productivity growth.

In the sixth row, it is tested for an additional impact of short-run productivity changes in the United States. To avoid a simultaneous equation bias, only the lagged variable is included. The coefficient proved (weakly) significant and indicates an additional spillover from short-run productivity advances.

In the next rows, the robustness of these results is tested. In version (7) the trend is omitted, which yields slightly higher coefficients for the capital-labour ratio and the domestic spillover, but leaves the other coefficients nearly unchanged. Versions (8)–(10) are dummy models. (8) and (9) include sectoral dummies. Including sectoral dummies without a trend (8) results in nearly unchanged coefficents, but the significance of the domestic capital-labour ratio and the productivity gap is reduced: a large part of the explanatory power of those variables comes from their cross-sectoral variation. Including, in addition, a time trend (9) renders the productivity gap completely insignificant. Probably, the multicollinearity between sectoral dummies, a time trend, and the productivity gap is too high to yield conclusive results. In version (10), only time dummies are included.[60] This yields again a significant coefficent for the productivity gap.

Version (11)–(13) correspond to (6), but are estimated for sub-periods, i.e. consecutive 10-year intervals. For the sixties (11), both the capital-labour ratio and the productivity gap are insignificant. This is due to the high correlation between these variables in this time period, which indicates that the catching-up in the sixties is mainly due to capital-deepening, without much additional role for knowledge spillovers. However, the short-run intra-sectoral spillover

[60]The productivity growth of the other sectors in Germany is excluded due to multicollinearity with the time dummies

coefficient is significant. In the seventies (12), knowledge spillovers were predominant. The respective coefficient is significant and its value is nearly identical to those of the corresponding stationarity test in table 1. In addition, the short-run spillover effect is significant. For the eighties (13), catching-up is only weakly significant, and the small part of sectoral productivity growth which is explained by the equation is due to changes in the capital-labour ratio and human capital.[61]

Finally, a corresponding model is estimated for the United States. The trend, the productivity gap, and the lagged German productivity growth rate were not significant, and were dropped for the reported equation. Since a sectoral business cycle indicator was not available, aggregate hours and capacity utilization were used instead. In contrast to the results for Germany, the lagged endogenous variable proved significant. The estimated elasticity of output with respect to capital is slightly lower than in Germany which may be partly due to the lack of a measure of sectoral capacity utilization. The other results are mainly comparable. The human capital indicator is significant, and the significance of inter-sectoral spillovers indicates a source of endogenous growth also for the United States.

The final table 3 contains estimates of the effects of the productivity gap on other sectoral variables. The specification is a reduced form estimate, were the rate of change of the respective variable is regressed on the productivity gap. In the equation, it is controlled for the business cycle. In addition, a complete set of time dummies and two lags of the endogenous variable are included. The results for the capital-labour ratio in the first rows confirm the above conclusions on the importance of capital-deepening for the catching-up: the productivity gap had a significant impact on changes of the capital-labour ratio only in the sixties. The results for the capital stock, employment, and output growth below indicate that the productivity advances through increases of the capital-labour ratio had no expansive effect on the development of the sector but reduced the labour input. Employment declined about in the amount of the productivity growth. A different conclusion can be drawn for the seventies. There is no significant impact of the productivity gap on the capital-labour ratio, but a weakly negative effect on employment and a weakly positive effect on output growth. The productivity advances via knowledge spillovers increased the output shares of the respective sectors. For the eighties, there is only a weakly significant effect on employment. Finally, the effects of the productivity gap on sectoral prices are about of the same amount as the effect on German productivity growth. Productivity advances from the catching-up were transmitted on to prices, but no additional price dampening effects from the existence of a high productivity leader sector were found.

[61] It was also tested for constant returns to scale at the sectoral level via the gross investment rate, the lagged level of human capital and the lagged level of the business cycle situation. The results were inferior to those reported. In addition, aggregate hours were not significant. The residual of the reported equations did not exhibit significant autocorrelation.

Table 3: Further effects of the productivity gap

	yl^d_{t-1}	Δu^g_t	lag1	lag2	$\overline{R}^2$	SEE
endogenous variable: Δkl^g_t						
1961-90	−0.004	−0.028	0.450	0.091	0.521	0.021
	(-1.64)	(3.75)	(10.75)	(2.25)		
1961-70	−0.011	−0.051	0.329	0.260	0.441	0.026
	(-2.10)	(-2.46)	(3.99)	(3.10)		
1971-80	−0.002	−0.026	0.459	−0.058	0.491	0.021
	(-0.37)	(-2.70)	(6.80)	(-0.96)		
1981-90	−0.000	−0.018	0.517	0.100	0.474	0.016
	(-0.01)	(-1.53)	(7.30)	(1.44)		
endogenous variable: Δk^g_t						
1961-90	0.003	0.004	0.665	0.195	0.820	0.012
	(2.11)	(1.05)	(16.02)	(4.86)		
1961-70	0.001	0.001	0.255	0.539	0.632	0.018
	(0.31)	(0.09)	(2.81)	(5.93)		
1971-80	0.001	0.006	1.040	−0.123	0.903	0.008
	(0.86)	(1.75)	(24.15)	(-3.19)		
1981-90	0.001	0.009	1.097	−0.162	0.941	0.005
	(0.75)	(2.29)	(16.31)	(-2.45)		
endogenous variable: Δl^g_t						
1961-90	0.009	0.028	0.573	−0.006	0.516	0.023
	(3.37)	(3.51)	(13.68)	(-0.14)		
1961-70	0.011	0.045	0.569	−0.001	0.511	0.024
	(2.26)	(2.31)	(7.08)	(-0.01)		
1971-80	0.008	0.027	0.599	−0.036	0.511	0.023
	(1.67)	(2.41)	(8.43)	(-0.53)		
1981-90	0.009	0.020	0.541	0.034	0.505	0.022
	(1.87)	(1.34)	(7.69)	(0.49)		
endogenous variable: Δy^g_t						
1961-90	−0.002	0.112	0.182	0.104	0.384	0.041
	(-0.40)	(7.83)	(4.56)	(2.54)		
1961-70	0.002	0.104	0.339	−0.050	0.460	0.039
	(0.30)	(3.24)	(4.32)	(-0.60)		
1971-80	−0.012	0.113	0.245	0.072	0.382	0.042
	(-1.36)	(5.78)	(3.53)	(1.06)		
1981-90	0.004	0.110	0.046	0.194	0.215	0.041
	(0.50)	(3.86)	(0.73)	(2.94)		
endogenous variable: Δp^g_t						
1961-90	0.018	0.035	0.262	−0.160	0.313	0.034
	(4.41)	(3.03)	(6.30)	(-3.88)		
1961-70	0.024	0.005	0.270	−0.298	0.397	0.036
	(3.28)	(0.18)	(2.93)	(-3.15)		
1971-80	0.025	0.047	0.194	−0.208	0.218	0.037
	(3.25)	(2.76)	(2.94)	(-3.21)		
1981-90	0.003	0.031	0.337	−0.004	0.243	0.027
	(0.59)	(1.68)	(5.24)	(-0.06)		

Sample: all industry sectors excluding mining, real estate.

4 Conclusions

The basic novelty of this study is the empirical analysis of the catching-up process based on a panel with sectoral data for the United States and Germany 1960–90. The advantage of cross-industry data is that country specifica of the growth process and data measurement can be taken seriously. The time-series dimension permits the separate analysis of sub-periods, and the extended number of disaggregated observations increases the data variation and allows a more rigorous empirical testing. The estimates revealed a well determined and reasonable estimate of the impact of physical capital on growth, and the role of human capital as a production factor was established.

The basic conclusion is that productivity catching-up of West Germany with respect to the United States had occurred. The productivity gap with respect to the United States has about the same explanatory power for labour productivity changes in Germany as capital accumulation. However, the result should be qualified for sub-periods. For the fifties, the special rôle of reconstruction growth should be mentioned which deserves a special treatment and is on the agenda for future research. The observed catching-up in the sixties is mainly due to capital-deepening with little additional role of knowledge spillovers. This corresponds to the increasing amount of world trade in this period which increases the market size and allows to employ capital-intensive techniques also in the smaller countries. In the seventies, no catching-up through capital-deepening was found, but knowledge spillovers were predominant. About three percent of the productivity gap were closed each year, and at the end of the seventies, Germany had achieved nearly eighty percent of the productivity level of the United States. No significant catching-up was found for the eighties. This corresponds to the about constant productivity gap in the eighties, German manufacturing even falls back behind the United States.

In addition to the effects from the productivity gap, the estimates revealed significant intra-sectoral spillovers from productivity growth in the United States, and significant inter-sectoral spillovers in Germany and in the United States. These spillovers indicate an inefficiency of a decentralized market system and imply scale economies at a more aggregate level. Therefore, they imply a source of endogenous growth not only for the less developed country but also for the productivity leader.

Finally, being behind had a significant dampening effect on employment and prices of the respective sectors in Germany. The size of these effects corresponds about to the effect on labour productivity. Productivity advances from the catching-up were transmitted on to prices and employment, but additional growth dampening effects were not found. Therefore, the negative effects from import penetration for the less developed sector appear less important than the positive effects from knowledge spillovers.

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Appendix

Table 4: Sectors

			output weight 1985	
			Germany	U.S.
2	agr	agriculture	0.018	0.021
3	mid	mining and quarrying	0.009	0.028
4	man	manufacturing	0.326	0.196
5	fod	food, beverages, and tobacco	0.035	0.020
6	tex	textiles	0.014	0.010
7	wod	wood and products	0.010	0.009
8	pap	paper, printing, and publishing	0.014	0.021
9	che	chemicals	0.061	0.030
10	mnm	non-metallic mineral products	0.012	0.006
11	bmi	basic metal products	0.025	0.009
12	meq	machinery and equipment	0.153	0.087
13	bma	metal products except machinery and transport	0.027	0.014
14	mai	agricultural, industrial machinery	0.037	0.031
15	mio	office and data processing mach., precision and optical instr.	0.010	0.006
16	mel	electrical goods	0.037	0.018
17	mtr	transport equipment	0.040	0.023
18	mot	other manufactured products	0.002	0.003
19	egw	electricity, gas, and water	0.028	0.031
20	cst	construction	0.053	0.046
21	ret	wholesale, retail trade, restaurants, hotels	0.101	0.168
22	rwh	wholesale, retail trade	0.088	0.161
23	hot	restaurants and hotels	0.012	0.008
24	trs	transport, storage, and communication	0.059	0.061
24a	trs	transport, storage	0.036	0.034
25	com	communication	0.023	0.027
26	fni	finance, insurance, and real estate	0.131	0.225
27	fns	finance and insurance	0.057	0.049
28	res	real estate	0.074	0.176
29	soc	community, social, pers. services	0.133	0.090
30	tin	total industries	0.859	0.882
31	pgs	producer of government services	0.117	0.118
32	opr	other producers	0.024	.
33	tet	total	1.000	1.000

Source: OECD (1993).

Table 5: Sectoral labour productivity growth

	YL^d				Δyl^g	Δyl^d
sector	1960	1970	1980	1989	1961-90	1961-89
2	0.204	0.254	0.446	0.556	0.060	0.035
5	0.715	0.760	0.699	0.619	0.019	-0.005
6	0.853	0.967	0.869	0.875	0.033	0.001
7	0.594	0.811	0.740	0.640	0.028	0.003
8	0.505	0.610	0.685	0.714	0.025	0.012
9	0.526	0.779	0.848	0.654	0.035	0.008
10	0.488	0.683	0.849	0.762	0.035	0.015
11	0.383	0.527	0.606	0.635	0.030	0.017
13	0.585	0.746	0.761	0.601	0.024	0.001
14	0.712	0.797	0.785	0.321	0.016	-0.027
15	0.475	0.591	0.798	0.608	0.035	0.009
16	0.727	0.800	0.794	0.764	0.045	0.002
17	0.606	0.735	0.794	0.661	0.027	0.003
18	0.944	0.957	0.985	0.869	0.020	-0.003
19	0.438	0.458	0.657	0.576	0.037	0.009
20	0.281	0.409	0.662	0.790	0.017	0.036
22	0.484	0.607	0.714	0.697	0.027	0.013
23	0.685	0.615	0.615	0.627	-0.005	-0.003
24	0.436	0.535	0.579	0.727	0.030	0.018
25	0.400	0.411	0.421	0.382	0.048	-0.002
27	0.674	0.976	1.324	1.541	0.032	0.029
29	1.315	1.484	1.541	1.660	0.017	0.008

YL^d: Relative labour productivity, Germany vs. U.S.
Δyl^g: Labour productivity growth, Germany
Δyl^d: Labour productivity growth, Germany vs. U.S.
Source: OECD, International Sectoral Statistics

Table 6: Aggregate labour productivity growth, Germany

	YL^d				Δyl^g			
time	agg	std	min	max	agg	std	min	max
1960	0.466	0.239	0.204	1.315				
1961	0.468	0.248	0.192	1.355	0.033	0.024	-0.051	0.047
1962	0.472	0.249	0.210	1.338	0.043	0.031	-0.009	0.112
1963	0.466	0.245	0.216	1.320	0.028	0.028	-0.023	0.097
1964	0.484	0.249	0.217	1.309	0.073	0.031	0.019	0.144
1965	0.496	0.263	0.201	1.371	0.051	0.022	-0.006	0.072
1966	0.507	0.260	0.215	1.399	0.034	0.032	-0.029	0.086
1967	0.526	0.261	0.230	1.425	0.037	0.041	-0.045	0.138
1968	0.550	0.262	0.261	1.433	0.062	0.052	-0.102	0.119
1969	0.582	0.268	0.251	1.491	0.064	0.031	0.012	0.128
1970	0.603	0.257	0.254	1.484	0.037	0.029	-0.018	0.094
1971	0.604	0.255	0.272	1.482	0.028	0.038	-0.050	0.110
1972	0.614	0.260	0.277	1.508	0.046	0.031	0.001	0.114
1973	0.632	0.254	0.322	1.487	0.044	0.042	-0.032	0.141
1974	0.662	0.253	0.370	1.472	0.020	0.041	-0.068	0.100
1975	0.665	0.244	0.350	1.451	0.014	0.039	-0.069	0.086
1976	0.699	0.245	0.364	1.450	0.070	0.050	0.006	0.195
1977	0.716	0.247	0.374	1.485	0.034	0.036	-0.034	0.109
1978	0.736	0.255	0.383	1.514	0.027	0.026	-0.033	0.077
1979	0.765	0.261	0.401	1.536	0.030	0.035	-0.021	0.113
1980	0.768	0.251	0.421	1.541	-0.007	0.058	-0.218	0.099
1981	0.766	0.255	0.386	1.531	0.006	0.032	-0.056	0.070
1982	0.775	0.258	0.433	1.534	0.008	0.062	-0.060	0.202
1983	0.787	0.265	0.391	1.588	0.036	0.038	-0.065	0.092
1984	0.794	0.264	0.405	1.621	0.031	0.026	-0.018	0.093
1985	0.795	0.274	0.399	1.597	0.019	0.032	-0.035	0.074
1986	0.794	0.285	0.389	1.609	0.013	0.058	-0.142	0.115
1987	0.794	0.299	0.360	1.631	0.006	0.032	-0.090	0.040
1988	0.805	0.304	0.320	1.662	0.034	0.034	-0.023	0.114
1989	0.822	0.308	0.321	1.660	0.023	0.051	-0.183	0.064
1990					0.021	0.031	-0.033	0.113

agg: total industries
std: standard deviation of sectoral values
min: minimum of sectoral values
max: maximum of sectoral values

Table 7: Stationarity tests

	Germany		U.S.		Difference		Difference with trend			
	Δyl^{g}_{t-1}		Δyl^{u}_{t-1}		yl^{d}_{t-1}		yl^{d}_{t-1}		trend	
	coef.	t	coef.	t	coef.	t	coef.	t	coef.	t
sectors										
2	-1.545	-4.66	-1.587	-5.53	-0.040	-0.72	-0.516	-2.58	0.020	2.46
5	-0.887	-3.27	-1.181	-3.95	-0.135	-1.00	-0.391	-2.29	-0.003	-2.20
6	-1.195	-4.53	-1.097	-3.57	-0.201	-1.62	-0.211	-1.67	-0.001	-0.73
7	-0.413	-2.14	-0.975	-3.99	-0.110	-1.36	-0.083	-1.01	-0.002	-1.31
8	-1.337	-5.60	-1.191	-4.29	-0.054	-0.93	-0.571	-2.87	0.008	2.69
9	-0.816	-3.01	-1.177	-4.20	-0.145	-2.15	-0.058	-0.66	-0.003	-1.52
10	-1.165	-4.00	-1.071	-3.96	-0.087	-1.96	-0.043	-0.47	-0.001	-0.54
11	-1.078	-4.08	-1.079	-3.85	-0.062	-1.05	-0.331	-2.16	0.009	1.88
13	-0.998	-4.02	-1.444	-5.49	-0.116	-1.70	-0.083	-1.04	-0.001	-0.84
14	-1.325	-4.96	-0.441	-2.14	0.027	0.32	-0.013	-0.16	-0.004	-1.93
15	-0.521	-1.64	-1.874	-5.27	-0.076	-1.25	0.222	1.15	-0.008	-1.62
16	-1.090	-4.20	-1.210	-4.09	-0.162	-1.52	-0.250	-1.57	0.001	0.75
17	-1.209	-4.24	-0.937	-3.97	-0.161	-1.51	-0.284	-1.60	0.003	0.87
18	-1.336	-4.75	-1.486	-4.72	-0.328	-2.30	-0.513	-3.14	-0.004	-2.01
19	-0.573	-2.47	-0.766	-2.80	-0.053	-0.99	-0.217	-1.60	0.004	1.32
20	-1.039	-3.99	-0.637	-3.25	-0.018	-1.05	-0.127	-1.60	0.005	1.40
22	-0.681	-3.17	-0.825	-3.78	-0.057	-1.46	-0.152	-1.32	0.002	0.87
23	-0.923	-3.24	-1.079	-3.67	-0.316	-2.36	-0.383	-2.20	-0.001	-0.61
24	-1.260	-4.92	-0.733	-3.21	-0.009	-0.17	-0.307	-2.57	0.006	2.70
25	-0.679	-2.95	-1.322	-4.43	-0.331	-2.67	-0.419	-3.14	0.001	1.55
27	-1.055	-4.13	-0.968	-2.98	-0.028	-1.33	-0.316	-2.34	0.009	2.15
29	-0.864	-4.06	-0.701	-2.95	-0.026	-0.49	-0.409	-2.67	0.003	2.63
all										
1961-90	-0.854	-15.87	-0.902	-16.45	-0.023	-3.67	-0.018	-2.90	-0.001	-2.39
1961-70	-0.919	-9.44	-0.563	-5.57	-0.014	-1.71	-0.018	-2.38	0.007	5.65
1971-80	-1.027	-9.91	-0.987	-10.39	-0.034	-3.33	-0.038	-3.67	0.003	2.36
1981-90	-0.996	-10.84	-0.963	-10.45	-0.004	-0.26	-0.003	-0.22	0.001	0.39
man										
1961-90	-0.972	-13.56	-1.030	-13.81	-0.051	-3.49	-0.037	-2.49	-0.001	-2.96
1961-70	-1.181	-8.84	-0.726	-5.14	-0.032	-1.74	-0.047	-2.86	0.010	5.33
1971-80	-1.211	-8.16	-1.231	-9.60	-0.070	-2.61	-0.080	-2.96	0.003	1.85
1981-90	-1.220	-10.50	-1.005	-8.15	-0.023	-0.56	-0.026	-0.60	-0.001	-0.23

Results of Dickey-Fuller tests with a constant and one lag.
Reported are the coefficients and the respective t-values.