ERASMUS UNIVERSITY ROTTERDAM

**ERASMUS SCHOOL OF ECONOMICS**

# MEASURING GERMANY'S ECONOMIC INTEGRATION: A STATISTICAL APPROACH

Supervisor:

*Prof. dr. J. -M. A. R. G. Viaene*

Second Reader:

*Dr. J. Emami-Namini*

Author:

*V. S. Zuiddam*

March, 2016

**Abstract:** This thesis measured the degree of economic integration of the reunified German states for the period between 1991 and 2011 by using the statistical method developed by Bowen, Munandar and Viaene. This approach is based on three theoretical predictions with respect to the distribution of output and production factors across the member states of an integrated economic area (IEA), where there are no barriers to goods and factor movements and policies are harmonized. Empirical results show that all predictions hold and that the distribution human capital is the furthest away from the theoretically expected one. The applied integration statistic indicates that during the covered period Germany became more economically integrated, however integration stagnated since 1999. A further East-West migration of higher educated is expected, but could be reduced through policy harmonization. Also the union of Bremen and Saarland with their circumambient states will lead to a distribution of human capital in Germany that is closer to what is theoretically expected.

***Keywords**: Economic Integration, Germany, Policy Harmonization, Production Factor Distribution, Bowen-Munandar-Viaene Method.*

***JEL Classification**: E13, F15, J24, O52, R23.*

## Preface

This master thesis is the result of my research on the internal economic integration of Germany for the period 1991 to 2011 and is conducted at the Erasmus University Rotterdam as the last part of my Master in International Economics.

On this occasion I would like to thank the employees of the 14 Statistical Offices of the Länder for all their help in collecting the necessary data. Without their help this research paper would not have been possible. My special appreciation goes out to Mr. Udo Kleinegees of the Federal Statistical Office, who was so kind to answer the numerous questions that I posed him. Furthermore, I would like to thank my thesis supervisor Prof. dr. Jean-Marie Viaene for his specialized guidance during the writing process and the insights that he provided. Also I would like to thank Dr. Julian Emami-Namini for pointing me in the right directions during the process of data collecting.

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# 1. Introduction

On the 3rd of October 2015 Germany modestly celebrated the 25th anniversary of its reunification. In 1990 the six East German states (Länder) of Berlin, Brandenburg, Mecklenburg-Vorpommern, Sachsen, Sachsen-Anhalt and Thüringen declared themselves part of the Federal Republic of Germany. At the end of 1990, almost all West German laws and institutions were imposed on East Germany. Suddenly, after 45 years of division all barriers between the East and West German economies were taken away (Sinn, 1991). The capitalistic and socialistic systems that were in place had created the inevitable differences between the economic situations in both countries. The two different ideologies also affected the social landscape, resulting in two different types of Germans, the so-called 'Ossies' and 'Wessies' (Faustmann, 2006). Unfortunately for reunited Germany, economical unification does not happen overnight and has proven to be a slow and painful process. Now, 25 years after the reunification, economic growth in the eastern German states is lagging behind their western counterparts and the unemployment rates in the eastern states are substantially higher. This lasting gap and the continuous migration from eastern to western states make Germans openly question the success of the reunification. Therefore policymakers still search for ways to improve the incomplete economical integration (Hall and Ludwig, 2006).

Not only the German economic integration, but also the European economic integration is the subject of a broader academic and public debate. Even though disadvantages of further European integration are subject of discussion, no one can deny that a large part of our prosperity came about by the free movement of production factors and goods. As a result we witnessed an increase in the efforts undertaken by other countries to establish or enlarge existing regional trade agreements (RTAs) in the last 30 years. The global surge in the amount of RTAs and their effect on the participating countries, has led to an increase in academic efforts to quantify the degree and effects of economic integration (Bowen et al., 2010).

The goal of this thesis is to measure the degree of economic integration of the reunified German states by using the statistical method developed by Bowen, Munandar and Viaene. This approach is based on three theoretical predictions with respect to the distribution of output and production factors across the member states of an integrated economic area (IEA), where there are no barriers to goods and factor movements and policies are harmonized.

The first prediction is that factor mobility among the member states of an IEA will result in the equal-share relationship. The equal-share relationship states that each member's share of total IEA output will equal its share of total IEA physical capital and human capital. The second prediction is that the distribution of output and factor shares across IEA members exhibits Zipf's law. This is a rank-share distribution that implies a specific relationship between a given share and its rank across the set of members. The share of the largest member is twice the size of the second largest member and three times the size of the third member, etc. The proposed observation of a Zipf's Law distribution of shares is rooted in the harmonization of policies between IEA members, resulting in expected randomness of the shares and the proposed distribution. The third prediction, given that Zipf's Law occurs, is that there is a limiting distribution of shares. This implies that the distribution and the size of shares within a series only depend on the number of members of that series. Lastly, the distance between the theoretically expected and the prevailing distribution of shares provides a measurement of economic integration (Bowen, et al., 2010, 2011).

Because of the federal characteristics of Germany, the value of the output and factor stocks of the individual German states for the period 1991-2011 could be collected, which enables the application of the Bowen-Munandar-Viaene method. A similar statistical approach in quantifying the degree of economic integration between the German federal states has not been conducted yet.

In its totality, this thesis aims to provide an answer to the following questions:

- Was Germany economically integrated before it became divided?
- How is Germany's economical integration performing according to other researchers?
- Is Germany economically integrated according to the standards of the Bowen-Munandar-Viaene method?
- What can be expected of the future economic integration of Germany?
- What policy recommendations can be made based on the results?

The structure of this thesis is as follows. An assessment of the history of German economic economic history will be made in chapter two and will provide an overview of the German economic history and political integration before the division, the subsequent economical divergence, and an overview of conducted economical policies after the reunification. The third chapter summarizes the academic literature on economic integration and the German integration in particular. It will present the results of other researchers on the subject and the broader applicability of using the reunification as a natural experiment. The fourth chapter will elaborate on the theoretical framework of the Bowen-Munandar-Viaene method. The fifth chapter presents the results of the statistical tests conducted to measure the economic integration of Germany, and will also contain a quantitative interpretation and policy recommendations. The conclusion is presented in chapter six and a more detailed description of the collected data can be found in the appendix.

# 2. History of German Economic Integration

The German economy is the driving force behind the European common currency and is the contemporary economic powerhouse on the continent. However, the Germany as we know it today only exists since 1990, while the first modern German state emerged only in 1871. Before this paper investigates the extent of Germany's contemporary economic integration, this section will cover the economic history of the modern German state, how it came into existence and developed into its current form, and the polices that it undertook in the last 25 years to spur its economic integration.

## 2.1 The Creation of the Modern German State

Modern Germany was created in January 1871, when the heads of state of the independent German states proclaimed the Prussian king Wilhelm I German emperor of a unified German Empire. However, this political unification of the German states did not automatically imply social and economical unity. In 1871, the economy of the German Empire was fragmented into several economic regions, caused by the differences in resource endowments between the regions and the preceding centuries without a central government (Stegarescu, 2005). The German unification itself was more the result of exogenous political events than the economical integration efforts that preceded the unification (Wolf, 2006).

The economic integration of the German states started in 1834 when the German Zollverein, a Prussian dominated customs union, was established. The Prussians used this customs union to impose their dominance on the other German states, via economic integration to increase their economic dependency on Prussia. After the enlargement of this customs union in 1854 it included almost all the German states that would form the German Empire in 1871 (Stegarescu, 2005). But this customs union did not automatically lead to a politically unified Germany and was not without its internal conflicts. For example, unification of the different legal systems of the German states came to a halt in the 1860's because of the resistance of the participating head of states, since unification under Prussian dominance would most certainly imply a loss of political power. This is why the majority of the then ruling nobility were initially against the unification in 1871 (Wolf, 2006).

## 2.2 Economic Integration before the Division

The unification of the German states in 1871 was possible because the Empire's constitution was a compromise reached between the German emperor and the states, which maintained the states' autonomy while the central powers of the empire were kept weak. The German states remained fully independent in maintaining their own taxation and financial systems. The heads of the German states had successfully resisted complete political and economical unification. As a result, at no time during the existence of the German Empire, had inter-state fiscal equalization existed. Besides the highly federal constitutional framework, there was another problem for the newly formed Germany. Namely, most economic activity was clustered around a few large cities and areas like Berlin, Hamburg and München. Other important industrial regions were the resources rich areas like the Ruhrgebiet, Sachsen and Oberschlesien (Stegarescu, 2005).

With production centres scattered across the empire and the states not willing to integrate any further, complete economic integration of the German Empire was hindered. In order to research the extent of economic integration within the Empire, Wolf (2008) analysed the trade flows between the German states compared to the states bordering Germany, for the years 1885, 1913 and 1933 with the use of a gravity model. Wolf shows that a considerable and significant tariff equivalent existed on trade flows within the German Empire (Wolf, 2008). Another explanation for the lack of economical integration of Germany is that Prussia comprised two-third of the German Empire (see map A.1 in the appendix), a booming Prussia and well performing German Empire would create the illusion of an economically well-integrated country.

After the First World War, the Weimar Constitution of 1919 radically altered the old imperial structure of Germany into a strong centralized federal system. All states lost their fiscal autonomy and became financially dependent on the central government (Stegarescu, 2005). The main reason for this centralization were the financial obligations that the Versailles Treaty imposed on the Weimar Republic. Wolf (2008) argued that after the centralization of policies it took the German state until 1933 to become economically well integrated for the first time.

## 2.3 The Economical Divergence of the Germanys

After the Second Word War, Germany was occupied by the four victorious allied countries of France, Great Britain the USA and the USSR and divided into four occupational zones (see map A.2 in the appendix). Disagreements between the Western powers and the Soviet Union about the future of Germany led to the formation of two independent German states in 1949. A democratic and free-market orientated West Germany emerged out of the British, French and US zones and a socialistic East Germany, with a planned economy, was established in the Soviet zone. The Germans became alienated from each other as the East German government gradually prevented contact between the populations of the two Germanys. The zenith of this policy was reached in 1961 with the construction of the Berlin Wall, eliminating all possibilities to travel freely between East and West Germany (Faustmann, 2006).

The West German state that emerged in 1949 and the current German state are both much more federalized then the preceding Weimar state, because there was a strong aversion amongst the Western powers to a centrally led German state. The political décor of the socialistic East German state (Demokratischer Zentralismus) could not have been a bigger contrast. Beside the different constitutional frameworks, the two Germanys had radically different economic structures. Where the West Germany economy was free market orientated, the East German economy was controlled by the state (Staatsliche Plankommission), as was common for Marxist-Leninist states. In 1952, East Germany reorganized its provinces (Länder) into fairly arbitrary drawn up districts (Bezirke), which held little to no autonomy (Stegarescu, 2005).

History taught us eventually the discontent of the East Germans with their state. For example, it was only with the help of the Soviet army that the East German government was able to suppress the Uprising of 1953. But in November 1989, with the fall of the Berlin Wall, the East German state finally collapsed, and the Länder, abolished in 1952, were re-established so they could declare themselves part of the West German federal state. After 45 years of political, economical and cultural division, the difficult process of reuniting the two German states started in 1990 (Görtemaker, 2009).

## 2.4 Economic Policies after the Reunification

In 1990, the East German states adopted all West German laws and institutions and started to make the transition from a state-planned economy to free-market oriented one. East German Marks were converted into Deutschmarks at a 1:1 rate to maintain competitiveness, and to provide the Eastern German citizens with a fair endowment for their start within the reunited German state (Sinn, 1991). Because the eastern German physical capital stock was in a deplorable state, two tax incentive programs were implemented to subsidize and promote capital investments in eastern Germany: The Development Area Law (Fördergebietsgesetz) and the Investment Subsidy Law (Investitionszulagengesetz). The Development Area Law provided extra capital depreciation possibilities to companies from 1991 to 1998. The Investment Subsidy Law supported private investment in eastern Germany by indirect and direct tax-exempt from 1991 to 2013 (Eichfelder and Schneider, 2014).

When the newly founded eastern German labour unions negotiated about the wage levels in 1991, the parties agreed to reach the western relative wage level within five years. The main reason for this outcome, instigated by the western labour unions, was the fear for the loss of jobs in western Germany. The legal and economical unification also included that the West German welfare system is now applied in eastern Germany. This proved to be a very costly endeavour, since the German social system provides for a minimum family income. The artificially high eastern German wages resulted in high unemployment rates, which led to enormous fiscal transfers towards the eastern German states. Between 1991 and 1999, the eastern German current account deficit was about half their GDP and two-thirds of their deficits were funded by the western states through the Fiscal Equalization Fund (Länderfinanzausgleich) and the Federal Supplement Fund (Bundesgänzungsabgabe) (Sinn, 2000).

# 3. Literature Overview

During the past 20 years we have witnessed a rise in the number of RTAs and in the negotiation activity to form them. Negotiations started in 2013 between the EU and the US to create a free trade area, the Transatlantic Trade and Investment Partnership (TTIP). The public debate around the TTIP resulted in a steep rise in the number of popular and scientific articles about the potential effects of the TTIP and economical integration in general. This section will provide an overview of the academic literature and the indicators used to measure economic integration. The second part of the section contains the results of the leading researchers on the German economic integration and the reunification in general.

## 3.1 Economic Integration as Academic Subject

To measure the depth of economic integration, one usually takes a closer look to the changes in behaviour macroeconomic variables that occur after economies are more integrated. Therefore, and IEA area must be more then a free trade area alone, factors of production and goods must be completely mobile, which results in the equation of the marginal products of the production factors. Mundell (1957) showed that factor movements and trade are substitutes of each other. Where later Markusen (1983) showed that also a complementary result could be achieved. In general, an IEA should have a certain distribution of factor endowments (Bowen et al., 2010, 2011). Therefore, indicators of economic integration would ideally be macroeconomic variables that behave in a certain fashion because the areas in which they occur are part of an IEA.

Because a single indicator to measure economic integration does not exist, several techniques and measure have been developed over time. This resulted in three groups of measurement indicators: institution-based indicators, outcome-based indicators, and factor-based indicators. Most popular measures are outcome-based indicators and are some sort of cross-country flow variable. Institution-based indicators reflect the level of institutional convergence or the policy harmonization across countries. This indicator does not take obstacles to trade and factor movements into account. Therefore, institutional convergence alone is an incomplete indicator. Outcome-based indicators are the most common methods for measuring economic integration between countries. These indicators combine foreign trade or investment flows between countries with gravity equations to evaluate these flows. The downside of these

indicators is that they are more an indicator of globalization or openness than an accurate measure for economic integration. A serious problem is that these techniques completely overlook the micro-foundations underlying an IEA. Those micro-foundations are reflected by the distribution of production factors and when an area is sufficiently integrated, it should be observable at the factor and factor price level (Prakash and Hart, 2000).

One particular popular factor-based is income convergence, which is based on Solow's (1956) neo-classical growth model. The mechanism behind income convergence through economic integration is the equation of the marginal products of labour, when factors of production are completely mobile. However, when New Growth theory was developed in the 1980's, Romer (1983) and Lucas (1988) concluded that there was no sign of income convergences between rich and poor countries. This contradiction of the original theory sparked the academic debate on income convergence, resulting in several modifications of the original Solow model. The concepts that are most widely accepted in the field of income convergence are those of *β-convergence,* the tendency that poorer countries grow faster then richer ones and *σ-convergence* which captures the decrease in income distribution between rich and poor countries (Barro and Sala-i-Martin, 1992).

## 3.2 Investigating the German Economic Integration

The three groups of measurement indicators that were described earlier are not all applicable in studying the economic integration of the German reunification. Investigating institutional convergence is not possible, since the eastern German states adopted all West German laws and institutions. With the complete integration of the institutions and the dissolution of the borders between East and West, most outcome-based indicators as measurement tool for economic integration could not be used either, as trade and investment flows between regions are usually accounted on a national level. Besides the data availability issues for inter-German trade flows, outcome-based indicators alone are a narrow measure of economic integration.

Most research on the economic integration of Germany has been conducted in the field of convergence. The problem of using convergence indicators alone to measure economic integration is that even in areas that are economically integrated, regional income differences still persist. For example, the US is a fully IEA and still differences in income levels and capital-labour ratios exist between regions (Bowen et al., 2011). One reason for this is that the

marginal product of capital is also dependent on complementary factors of production and efficiency. This is why differences in capital-labour ratios and income can occur and the convergence of them is absent within an IEA (Caselli and Feyrer, 2006).

After ten years of reunification, many assessments of Germany's economic integration have been made by prominent academics, such as Michael C. Burda, Hans-Werner Sinn, Joachim Ragnitz and Robert Barro. Burda and Hunt (2001) concluded that the transition of former East German state was successful on many levels, especially the convergence of consumption and GDP per capita. Even though they found that GDP convergence has halted, they found a full convergence in the wage structure. Ten years after unification they found a persistent productivity gap, which is constant across skill levels. However, these results are more encouraging than Barro's (1991) prediction, that it would take several generations before the eastern German states would catch up and close the productivity gap of 70%. There has been a significant reallocation in the factors of production within Germany. Massive amounts of capital have flown from west to eastern Germany. Human capital however displayed an East-West flow pattern. Since 1991, 10% of the initial East German population had migrated westwards and migration numbers are rising again since 2000 (Burda, 2006). Sinn (2000) also found a halt in the convergence of per capita output. Sinn names several reasons for the persistence of this gap: the termination of the investment subsidy law, economic stagnation and high unemployment. Sinn also found that the standards of living were almost converged. In 2000, real household income in eastern German states was 90% of western German states.

Twenty years after the reunification, Burda (2010) found a GDP per capita gap of 29%, a labour productivity gap of 21% and twice the unemployment between eastern and western German states. Burda predicts a steady growth of the East German economy against a slowly decreasing population, resulting in an economically vital eastern Germany at the geographical centre of the European Union. Both Burda (2010) and Sinn (2000) found that convergence between eastern and western Germany faded out in the late nineties. Burda found that convergence stagnated in the last 15 years, which is supported by Solmy (2011), Brenke (2014) and Ragnitz (2015).

Since there is general consensus between academics that convergence between eastern and western Germany has halted since 1999, the remaining productivity gap is now the main focus of academic research. Especially the role of human capital, together with the industrial structures and industrial policy, are thought to be main causes of the persistent productivity gap. The policies of the nineties were mainly focused on industrial production and not on the transition towards a more human capital and service-intensive economy (Klodt, 1999). Hall and Ludwig (2007) state that the eastern German unemployment, caused by the productivity gap, is solely caused by labour market imperfections that are generated by policy mistakes after the unification, which is supported by Merkl and Snower (2008). Ragnitz (2007) foresees a further deterioration of the eastern German human capital stock because of selective emigration to western Germany. According to Ragnitz, this is because of the high unemployment and the low human capital intensity of production, caused by the previously implemented policies.

### 3.3 The German Reunification and Natural Experiments

Besides the investigation of Germany's economic integration, the reunification of Germany is also studied because it provides the setting for a natural experiment for testing economic theory. Redding et al. (2011) use the division of Germany and its reunification as an exogenous shock to industry location. Based on fundamentals there would be a unique steady state distribution of economic activity. After shocks the distribution of economic activity is expected to gravitate back towards the distribution based on these fundamentals. New economic geography models allow for multiple steady states, where the distribution of economic activity depends on history and shocks. They find that division leads to a reallocation of airport activity from Berlin to Frankfurt, but no return of activity to Berlin after the reunification. They show that this redistribution to Frankfurt cannot be predicted based on current economic fundamentals. By using the reunification as a natural experiment, they conclude that multiple steady states in industry location independent of fundamentals exist. This work is preceded by the paper Redding and Sturm (2008), where they exploit the German division and reunification as a natural experiment to provide evidence for the importance of market access for economic development, which are in line with new economic geography models.

The reunification as natural experiment can be applied on a broader range of research subjects. For example, Fuchs-Schündeln (2008) investigates the validity of the life-cycle consumption model and the relative importance of the precautionary savings motive by using the difference in saving behaviour between eastern and western Germans in reaction to the reunification. Whereas Schnettler and Klüsener (2014) use the reunification setting to test if the sex ratio at birth decreases after economical decline. While Rinne and Zhao (2010) use this setting to test Becker's theory of human capital and Spence's signalling approach towards education. Here they use the variation in the influence of the political system on curricula across fields on study in university education. In conclusion, many different subjects can be studied within the setting of the German reunification.

# 4. Theoretical Framework

This chapter will further elaborate the three theoretical predictions of the Bowen-Munandar-Viaene method and the proposed measure of economic integration. If countries are fully integrated, they will exchange factors of production, up to the point that the marginal products of the production factors is equalized in all countries, resulting in the optimal distribution of the production factors. This implies that the factor and output shares will be equally distributed among the IEA member states. As a result of policy harmonization across IEA members, Zipf's Law is expected to occur. This implies that there is a limiting distribution of shares, which depends only on the number of members. The difference between the observed and theoretical expected distribution of shares provides for a measure of the degree of economic integration.

## 4.1 The Equal-Share Relationship

The first theoretical prediction is based on the neo-classical Cob-Douglas production function, where output (real GDP) depends on two input factors: human capital and physical capital and with constant returns to scale. In the case of a fully IEA with $M$ number of members, the aggregated production function will have the following form:

(4.1) $$Y_{mt} = A_{mt} K_{mt}^{\alpha_m} H_{mt}^{1-\alpha_m} \qquad m = 1, \dots, M.$$

In this expression, $Y_{mt}$ is the quantity produced is, $K_{mt}$ the stock of physical capital and $H_{mt}$ the stock of human capital of member $m$ at time $t$. Technology is represented by parameter $A_{mt}$ and $\alpha_m$ and $1 - \alpha_m$ are the factor shares used in the production process. When there are no trade barriers between the $M$ IEA members, trade will increase up to the point that commodity prices are equalized in all member countries. Also, if factors of production are fully mobile, they will be exchanged between the IEA members until the marginal products of the factors are equalized between all members. The harmonization of policies, the absence of technological differences and market imperfections are a necessity to prevent any differences in the real marginal products.

Under these conditions, full economic integration between member states will then also lead to the same factor ratios used in the production process in each country. As a result: when a country possesses 10% of the total physical capital stock within the IEA, it also will account

for 10% of the total human capital stock and 10% of the total output of the IEA. This is called the equal-share relationship:

(4.2) $$\frac{Y_{it}}{\sum_{m=1}^{M} Y_{mt}} = \frac{K_{it}}{\sum_{m=1}^{M} K_{mt}} = \frac{H_{it}}{\sum_{m=1}^{M} H_{mt}}.$$

Where $i = 1, \dots, M$ is the number of IEA member states. The equal-share relationship is the first theoretical prediction to hold according to the Bowen-Munandar-Viaene method within an IEA.

## 4.2 Zipf's Law

The second theoretical prediction is that distribution of output and factor shares among members will exhibit Zipf's law. Complete harmonization of policies implies that any changes that occur are thought to be random. Harmonization of policies is characterized by the ex-ante specification of ex-post targets, mostly in relative terms than in absolute ones. Implementation of harmonized policies is simplified through the establishment of common goals. When shares evolve randomly, the distribution becomes a Zipf's Law distribution, which is a rank-share distribution that is characterized by a specific relationship between a given share and its rank within the series. Here it implies that the share of the highest ranked member is twice the size the share of the second ranked member, three times the size the share of the third ranked member, etc.

The share of IEA member $m$ in total IEA amount of variable $j$ as is denoted as $S_{mj}$, with $j = y, k \; or \; h$, being output, physical capital and human capital respectively. The rank of IEA member $m$ his shares in variable $j$ across all IEA members ($m = 1, \dots, M$) is denoted as $R_{mj}$. With $R_{mj} = 1$ for the member state with the largest share in variable $j$ and $R_{mj} = M$ for the member state with the lowest share. When the variable $j$ has a power-law distribution we can derive:

(4.3) $$S_{mj} = \gamma_j \left(R_{mj}\right)^{\beta_j}.$$

The relationship above implies the following specific relationship among the shares:

(4.4) $$\frac{S_{1j}}{S_{2j}} = 2^{-\beta_j}, \frac{S_{1j}}{S_{3j}} = 3^{-\beta_j}, \dots, \frac{S_{1j}}{S_{Mj}} = M^{-\beta_j}.$$

The expression in (4.4) implies that the complete distribution of shares depends on the values that are assigned to $\beta_j$ and $M$. For a Zipf's law distribution, where: $\beta_j = -1$, (4.4) can be simplified as:

(4.5) $$S_{1j} = 2S_{2j} = 3S_{3j} = \cdots = MS_{Mj}.$$

This implies that the share of the highest ranked state is twice the size the share of the second ranked state, three times the size the share of the third ranked, etc.

## 4.3 Limiting Distribution of Shares

The third theoretical prediction is, if the shares are Zipf's law distributed, that the value of shares will only depend on the number of IEA members. Then difference between the observed and the uniquely expected values of the shares can serve as an integration benchmark, whereby the extent of economic integration can be quantified.

We denote $V_{mj}$ as the level of variable $j$ for IEA member $m$ and $\delta_{mj}$ as the ratio of member $m$'s value of variable $j$ relative to that the largest member. This gives: $\delta_{mj} = V_{mj}/V_{1j}$ and $\delta_{mj} = 1$, with the total amount of variable $j$ in the IEA being:

(4.6) $$V_{1j}\left(1 + \delta_{2j} + \delta_{3j} + \cdots + \delta_{Mj}\right).$$

This implies the following relationship between the member state rank and shares:

(4.7) $$Rank\ 1: \quad S_{1j} = \frac{1}{1+\delta_{2j}+\delta_{3j}+\cdots+\delta_{Mj}}$$

(4.8) $$Rank\ 2: \quad S_{2j} = \frac{\delta_{2j}}{1+\delta_{2j}+\delta_{3j}+\cdots+\delta_{Mj}}$$

(4.9) $$Rank\ M: \quad S_{Mj} = \frac{\delta_{Mj}}{1+\delta_{2j}+\delta_{3j}+\cdots+\delta_{Mj}}.$$

This implies that the sequence of shares is a harmonic series, where each share value ($S_{mj}$) depends on the ratio of member $m$'s value of variable $j$, relative to that of largest member ($\delta_{mj}$) and the number of IEA members ($M$). In the case of 16 German states, the share in variable $j$ of the largest German state would be 29.58%, of the total amount of variable $j$:

(4.10) $$Rank\ 1: \quad S_{1j} = \frac{1}{1+\delta_{2j}+\delta_{3j}+\cdots+\delta_{16j}} = 0.2958.$$

### 4.4 Kullback-Leibler Divergence

The degree of economic integration is computed by measuring by the distance between the theoretically expected and the actual distribution of shares, with the use of Kullback-Leibler Divergence (KLD). Here, Symmetric Kullback-Leibler divergence (SKLD) is preferred because it accounts for situations where the two distributions deviate around a common mean, which can lead to a KLD value of zero:

(4.11) $$SKLD(\bar{S}_t, S_t) = \frac{1}{3}\sum_{j=Y,K,H}\left(\sum_{m=1}^{M}(\bar{S}_{mj} - S_{mj})\ln\left(\frac{\bar{S}_{mj}}{S_{mj}}\right)\right).$$

With $\bar{S}_{mj}$ being the theoretical predicted share of member $m$ and $S_{mj}$ the observed share. To quantify the total degree of economic integration, SKLD is used to measure the distance between the arithmetic average of output, physical capital and human capital share and the postulated Zipf's Law distribution.

As the value of SKLD ranges from zero (full integration) to infinity, it is more convenient to transform the SKLD into the following form:

(4.12) $$ISKLD(\bar{S}_t, S_t) = \frac{1}{e^{SKLD(\bar{S}_t, S_t)}} = e^{-SKLD(\bar{S}_t, S_t)}.$$

Inverted SKLD (I-SKLD) provides a single measure for the degree of integration between 0 and 1. Where a value of 1 indicates that the member states are fully economically integrated and the further the value is from 1, the less well integrated the IEA is.

# 5. Results

In this chapter the results of the statistical tests on the previously explained theoretical predictions will be presented. These tests will be conducted on the factor and output shares of the 16 German federal states, for all years between 1991 and 2011. Also the results of the integration measure and its development during the covered time period are presented. A quantitative interpretation of those results will be provided. Lastly, expectations with respect to future inner-German migration and policy recommendations are given in the last section.

## 5.1 Testing the Equal-Share Relationship with Spearman's Rho

The statistic used to test if the equal-share relationship holds between the German federal states is the Spearman-rank correlation coefficient (Spearman's rho). Which measures the conformity between the pair-wise ranks of the output, physical capital and human capital shares of the German federal states. This tests a "weak" form of the equal-share relationship since it measures the correlation between ranks of the shares and not between the share values directly. This allows testing for a more realistic and "less then perfect" form of the equal-share relationship. Since there are cases in which the shares and marginal products cannot perfectly equate, because of immobile factors like land and natural resources or transportation costs.

Table 5.1 presents the results of the rank correlations output and physical capital, output and human capital and between physical capital and human capital for the 16 German federal states between 1991 and 2011. All correlations are significantly different from zero at a 1% confidence level. The rank correlation between output and physical capital was already high in 1991 and is almost 1-to-1 in 2011, indicating that the equal-share relationship between output and physical capital holds within Germany. The rank correlations between human capital and output and physical capital and human capital were both much lower in 1991. Between 1991 and 2011 these rank correlations increased tremendously, caused by the redistribution of factors within Germany after the reunification. However, the rank-correlation between human capital and both output and physical capital is not as high as between output and physical capital. Since human capital is the least mobile variable of interest this slower redistribution can be accounted for.

**Table 5.1**: Spearman Rank Correlations to Test the Equal-Share Relationship[a]

| | | Spearman Rank Correlation between Shares of | | |
|---|---|---|---|---|
| Economic Group | Year | Output and Physical Capital | Output and Human Capital | Physical and Human Capital |
| 16 German | 1991 | 0.976 | 0.747 | 0.725 |
| Federal States | 1992 | 0.968 | 0.762 | 0.756 |
| | 1993 | 0.965 | 0.862 | 0.832 |
| | 1994 | 0.979 | 0.844 | 0.838 |
| | 1995 | 0.982 | 0.847 | 0.806 |
| | 1996 | 0.985 | 0.865 | 0.841 |
| | 1997 | 0.985 | 0.850 | 0.868 |
| | 1998 | 0.988 | 0.850 | 0.888 |
| | 1999 | 0.985 | 0.853 | 0.888 |
| | 2000 | 0.988 | 0.865 | 0.897 |
| | 2001 | 0.988 | 0.865 | 0.897 |
| | 2002 | 0.979 | 0.847 | 0.900 |
| | 2003 | 0.979 | 0.862 | 0.915 |
| | 2004 | 0.976 | 0.850 | 0.903 |
| | 2005 | 0.979 | 0.859 | 0.906 |
| | 2006 | 0.979 | 0.879 | 0.932 |
| | 2007 | 0.976 | 0.876 | 0.932 |
| | 2008 | 0.982 | 0.897 | 0.932 |
| | 2009 | 0.982 | 0.915 | 0.944 |
| | 2010 | 0.982 | 0.915 | 0.944 |
| | 2011 | 0.982 | 0.915 | 0.944 |

Note: [a]All coefficients exceed 0.635 and therefore significantly differ from zero at a 1% confidence interval (Zar, 1972).

## 5.2 Testing Zipf's Law with Regression Analysis

Testing if the distribution of shares conforms to a rank-share distribution that exhibits Zipf's law is done through regression analysis. A linear relationship is obtained by taking, natural logarithm of both sides of expression (4.3):

(5.1) $$\ln(S_{mj}) = \theta_j + \beta_j \ln(R_{mj}) + u_{mj}.$$

Where $\theta_j = \ln(\gamma_j) < 0$ is the log of the highest ranking member's share in variable $j$ and $u_{mj}$ is the error term. The estimates of the intercept ($\hat{\theta}_j$) and slope ($\hat{\beta}_j$), for the output and production factors are obtained by regressing the share values on their rank values. Tests are performed if $\hat{\beta}_j$ significantly differs from -1, as would be the case when the distribution exhibits Zipf's Law.

According to Bowen et al. (2011), the estimated $\hat{\beta}_j$ and its associated standard error are biased downwards. This bias of the estimated slope coefficient is corrected with $0.168$ and the asymptotic estimation of the true standard error of the bias-corrected slope is computed as $-\hat{\beta}_j\sqrt{2/M}$.[1]

**Table 5.2**: Output OLS Estimates to Test Zipf's Law[a]

| Share Variable | Year | Intercept | Slope | Bias-Corrected Slope = -1 | Z-Statistic Testing Bias-Corrected Slope = -1[b] | Adj. $R^2$ |
|---|---|---|---|---|---|---|
| Output (N = 16) | 1991 | -0.854 (0.198) | -1.266 (0.096) | -1.098 | -0.219 | 0.920 |
| | 1992 | -0.885 (0.188) | -1.240 (0.091) | -1.072 | -0.164 | 0.924 |
| | 1993 | -0.933 (0.180) | -1.198 (0.087) | -1.030 | -0.071 | 0.926 |
| | 1994 | -0.967 (0.173) | -1.170 (0.084) | -1.002 | -0.005 | 0.928 |
| | 1995 | -0.982 (0.171) | -1.157 (0.083) | -0.989 | 0.027 | 0.929 |
| | 1996 | -0.986 (0.174) | -1.154 (0.084) | -0.986 | 0.034 | 0.926 |
| | 1997 | -0.990 (0.172) | -1.151 (0.083) | -0.983 | 0.042 | 0.927 |
| | 1998 | -0.982 (0.173) | -1.159 (0.084) | -0.991 | 0.022 | 0.927 |
| | 1999 | -0.981 (0.173) | -1.160 (0.084) | -0.992 | 0.020 | 0.927 |
| | 2000 | -0.975 (0.172) | -1.165 (0.083) | -0.997 | 0.007 | 0.929 |
| | 2001 | -0.971 (0.174) | -1.170 (0.084) | -1.002 | -0.005 | 0.928 |
| | 2002 | -0.969 (0.171) | -1.171 (0.083) | -1.003 | -0.007 | 0.930 |
| | 2003 | -0.972 (0.172) | -1.169 (0.083) | -1.001 | -0.002 | 0.929 |
| | 2004 | -0.973 (0.170) | -1.168 (0.082) | -1.000 | 0.027 | 0.930 |
| | 2005 | -0.976 (0.170) | -1.160 (0.082) | -0.992 | 0.020 | 0.930 |
| | 2006 | -0.972 (0.173) | -1.170 (0.084) | -1.002 | -0.005 | 0.928 |
| | 2007 | -0.966 (0.173) | -1.176 (0.084) | -1.008 | -0.019 | 0.929 |
| | 2008 | -0.964 (0.174) | -1.176 (0.084) | -1.008 | -0.019 | 0.928 |
| | 2009 | -0.960 (0.176) | -1.177 (0.085) | -1.009 | -0.022 | 0.927 |
| | 2010 | -0.957 (0.177) | -1.181 (0.086) | -1.013 | -0.031 | 0.927 |
| | 2011 | -0.948 (0.179) | -1.190 (0.087) | -1.022 | -0.052 | 0.926 |

Note: [a]Standard errors are in brackets. [b]$Z = \frac{(\hat{\beta}_j + 0.168) - (-1)}{-\hat{\beta}_j\sqrt{2/M}}$ and all bias-corrected slopes for Y, K and H do not significantly differ from -1 at a 1% confidence level.

[1] Corrections are based on computations of Bowen et al. (2011) and corrected for 16 observations.

The estimated slope coefficients of equation 5.1 for output, physical capital and human capital are presented in the Tables 5.2, 5.3 and 5.4 respectively. The distribution of output and physical capital stock statistically exhibit Zipf's law, with adjusted-$R^2$'s exceeding 0.9 and all the Z-scores indicating that the slopes do not significantly differ from -1, at a 1% confidence level. Statistically, the distribution of all variables exhibit Zipf's law, but the observed adjusted-$R^2$ of human capital is lower than those of output and physical capital. Relative to output and physical capital, the distribution human capital is the furthest away from the theoretically expected distribution. However, as was the case with the equal-share relationship, the distribution of human capital improved the most over the covered time period and is expected to redistribute further.

**Table 5.3**: Physical Capital OLS Estimates to Test Zipf's Law[a]

| Share Variable | Year | Intercept | Slope | Bias-Corrected Slope = -1 | Z-Statistic Testing Bias-Corrected Slope = -1[b] | Adj. $R^2$ |
|---|---|---|---|---|---|---|
| Physical Capital | 1991 | -0.806 (0.209) | -1.307 (0.101) | -1.139 | -0.301 | 0.917 |
| (N = 16) | 1992 | -0.846 (0.197) | -1.274 (0.095) | -1.106 | -0.235 | 0.922 |
| | 1993 | -0.880 (0.189) | -1.245 (0.091) | -1.077 | -0.175 | 0.925 |
| | 1994 | -0.906 (0.183) | -1.224 (0.089) | -1.056 | -0.129 | 0.927 |
| | 1995 | -0.942 (0.178) | -1.193 (0.086) | -1.025 | -0.059 | 0.928 |
| | 1996 | -0.942 (0.178) | -1.193 (0.086) | -1.025 | -0.059 | 0.927 |
| | 1997 | -0.960 (0.178) | -1.178 (0.086) | -1.010 | -0.024 | 0.925 |
| | 1998 | -0.974 (0.178) | -1.166 (0.086) | -0.998 | 0.005 | 0.923 |
| | 1999 | -0.986 (0.179) | -1.156 (0.087) | -0.988 | 0.029 | 0.922 |
| | 2000 | -0.994 (0.179) | -1.149 (0.087) | -0.981 | 0.047 | 0.921 |
| | 2001 | -0.999 (0.180) | -1.145 (0.087) | -0.977 | 0.057 | 0.919 |
| | 2002 | -1.002 (0.180) | -1.143 (0.087) | -0.975 | 0.062 | 0.919 |
| | 2003 | -1.005 (0.182) | -1.141 (0.088) | -0.973 | 0.067 | 0.917 |
| | 2004 | -1.009 (0.183) | -1.138 (0.089) | -0.970 | 0.075 | 0.916 |
| | 2005 | -1.011 (0.184) | -1.136 (0.089) | -0.968 | 0.080 | 0.915 |
| | 2006 | -1.013 (0.185) | -1.135 (0.090) | -0.967 | 0.080 | 0.914 |
| | 2007 | -1.015 (0.187) | -1.133 (0.090) | -0.965 | 0.087 | 0.912 |
| | 2008 | -1.016 (0.188) | -1.132 (0.091) | -0.964 | 0.090 | 0.911 |
| | 2009 | -1.016 (0.190) | -1.132 (0.092) | -0.964 | 0.090 | 0.909 |
| | 2010 | -1.017 (0.192) | -1.131 (0.093) | -0.963 | 0.093 | 0.907 |
| | 2011 | -1.017 (0.193) | -1.132 (0.094) | -0.964 | 0.090 | 0.906 |

Note: [a]Standard errors are in brackets. [b]$Z = \frac{(\hat{\beta}_j + 0.168) - (-1)}{-\hat{\beta}_j \sqrt{2/M}}$ and all bias-corrected slopes for Y, K and H do not significantly differ from -1 at a 1% confidence level.

**Table 5.4**: Human Capital OLS Estimates to Test Zipf's Law[a]

| Share Variable | Year | Intercept | Slope | Bias-Corrected Slope = -1 | Z-Statistic Testing Bias-Corrected Slope = -1[b] | Adj. $R^2$ |
|---|---|---|---|---|---|---|
| Human Capital | 1991 | -1.180 (0.318) | -0.994 (0.154) | -0.826 | 0.495 | 0.730 |
| (N = 16) | 1992 | -1.161 (0.300) | -1.008 (0.146) | -0.840 | 0.449 | 0.758 |
| | 1993 | -1.150 (0.293) | -1.018 (0.142) | -0.850 | 0.417 | 0.771 |
| | 1994 | -1.153 (0.296) | -1.015 (0.144) | -0.847 | 0.426 | 0.765 |
| | 1995 | -1.165 (0.299) | -1.006 (0.145) | -0.838 | 0.455 | 0.759 |
| | 1996 | -1.172 (0.293) | -1.000 (0.142) | -0.832 | 0.475 | 0.765 |
| | 1997 | -1.151 (0.287) | -1.016 (0.139) | -0.848 | 0.423 | 0.777 |
| | 1998 | -1.135 (0.296) | -1.028 (0.143) | -0.860 | 0.385 | 0.771 |
| | 1999 | -1.127 (0.312) | -1.035 (0.151) | -0.867 | 0.363 | 0.753 |
| | 2000 | -1.119 (0.327) | -1.041 (0.158) | -0.873 | 0.345 | 0.737 |
| | 2001 | -1.107 (0.329) | -1.050 (0.160) | -0.882 | 0.318 | 0.738 |
| | 2002 | -1.101 (0.325) | -1.055 (0.157) | -0.887 | 0.303 | 0.745 |
| | 2003 | -1.108 (0.312) | -1.049 (0.151) | -0.881 | 0.321 | 0.759 |
| | 2004 | -1.123 (0.294) | -1.037 (0.142) | -0.869 | 0.357 | 0.777 |
| | 2005 | -1.105 (0.280) | -1.051 (0.136) | -0.883 | 0.315 | 0.797 |
| | 2006 | -1.099 (0.289) | -1.056 (0.140) | -0.888 | 0.300 | 0.788 |
| | 2007 | -1.070 (0.298) | -1.079 (0.144) | -0.911 | 0.233 | 0.785 |
| | 2008 | -1.093 (0.274) | -1.061 (0.133) | -0.893 | 0.285 | 0.807 |
| | 2009 | -1.081 (0.275) | -1.072 (0.133) | -0.904 | 0.253 | 0.809 |
| | 2010 | -1.098 (0.262) | -1.058 (0.127) | -0.890 | 0.294 | 0.820 |
| | 2011 | -1.107 (0.253) | -1.051 (0.123) | -0.883 | 0.315 | 0.828 |

Note: [a]Standard errors are in brackets. [b]$Z = \frac{(\hat{\beta}_j + 0.168) - (-1)}{-\hat{\beta}_j \sqrt{2/M}}$ and all bias-corrected slopes for Y, K and H do not significantly differ from -1 at a 1% confidence level.

## 5.3 Testing for a Limiting Distribution of Shares

To test the third proposition, if the distribution of output and factor across the German federal state is unique and depends only on the number of states, the correlation between the natural logarithms of the actual and theoretical shares 1991 and 2011 is computed. These correlation coefficients are presented is Table 5.6. The theoretical shares of the 16 German states are shown in Table 5.5.

**Table 5.5**: Theoretical Share Values

| Economic Group | Theoretical Share Values (Descending) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 16 German | 0.2958 | 0.1479 | 0.0986 | 0.0739 | 0.0592 | 0.0493 | 0.0423 | 0.0370 |
| Federal States | 0.0329 | 0.0296 | 0.0269 | 0.0246 | 0.0228 | 0.0211 | 0.0197 | 0.0185 |

The distribution output and physical capital follow the harmonic series we would expect within a fully IEA. Again, the computed values for the distribution of human capital are lower. Even though the correlation coefficients of human capital increased during the covered period, further improvement is possible. Nevertheless, the distribution of output and production factors within Germany are distributed the way we would expect within a fully IEA on a statistical level.

**Table 5.6**: Correlations between Logarithm of Actual and Theoretical Shares

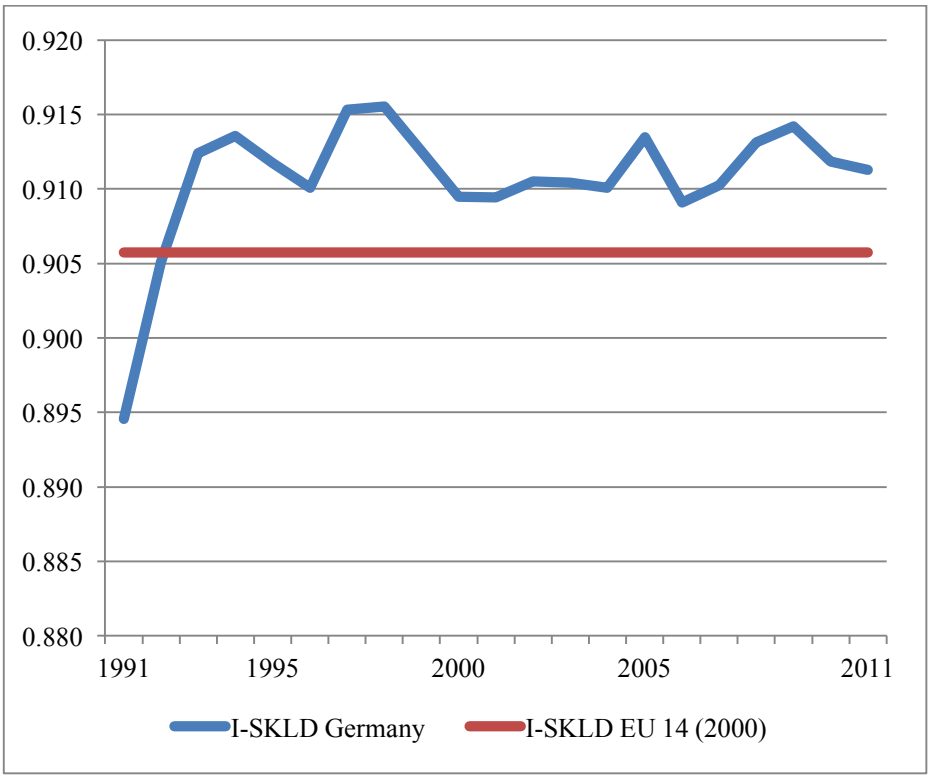
| | | Correlation Between the Log of Actual and Theoretical Shares | | |
|---|---|---|---|---|
| Economic Group | Year | Output | Physical Capital | Human Capital |
| 16 German | 1991 | 0.962 | 0.960 | 0.865 |
| Federal States | 1992 | 0.964 | 0.963 | 0.880 |
| | 1993 | 0.965 | 0.964 | 0.887 |
| | 1994 | 0.966 | 0.965 | 0.884 |
| | 1995 | 0.966 | 0.966 | 0.880 |
| | 1996 | 0.965 | 0.965 | 0.883 |
| | 1997 | 0.965 | 0.964 | 0.890 |
| | 1998 | 0.965 | 0.964 | 0.887 |
| | 1999 | 0.965 | 0.963 | 0.877 |
| | 2000 | 0.966 | 0.962 | 0.869 |
| | 2001 | 0.966 | 0.962 | 0.869 |
| | 2002 | 0.967 | 0.961 | 0.873 |
| | 2003 | 0.966 | 0.961 | 0.881 |
| | 2004 | 0.967 | 0.960 | 0.890 |
| | 2005 | 0.967 | 0.959 | 0.900 |
| | 2006 | 0.966 | 0.959 | 0.896 |
| | 2007 | 0.966 | 0.958 | 0.894 |
| | 2008 | 0.966 | 0.957 | 0.905 |
| | 2009 | 0.965 | 0.957 | 0.906 |
| | 2010 | 0.965 | 0.956 | 0.912 |
| | 2011 | 0.965 | 0.955 | 0.916 |

## 5.4 Economic Integration Measure

Figure 5.1 graphically displays the integration measure (equation 4.12) for all years between 1991 and 2011, with the value of the measure for the EU-14 countries in the year 2000 included as a benchmark (Bowen et al., 2010). Over the whole period Germany became more economically integrated, even though integration stagnated since 1999. Germany surpassed the EU-14 countries in terms of economical integration in 1993 and has stayed more integrated ever since. The stagnation of German economic integration in the late nineties is conforming the academic literature covered in the third chapter. The sudden decline after

2009 suggests that the great recession of 2007-2009 negatively influences the economic integration of Germany.

**Figure 5.1**: I-SKLD for Germany 1991-2011




## 5.5 Quantitative Interpretation of the Results

The distributions of output and factors of production within Germany are statistically distributed the way that would be expected within a fully IEA. So to provide a more comprehensive analysis, the ranks of the shares of output and the production factors for 1991 and 2011 are presented in Table 5.7. Between 1991 and 2011 the share ranks improved in exhibiting the equal-share relationship, especially the difference between the human capital ranks and the other ranks decreased. The ranks of human capital shares of the eastern German states, with the exception of Mecklenburg-Vorpommern, are still too high in terms of their output and/or physical capital ranks. This contrasts sharply with the western German states, whose human capital share ranks are too low in terms of the ranks of their other shares.

The equal-share relationship can also be interpreted as a reflection of per state productivity. Namely, human capital and physical capital together determine the amount of output. The 2011 ranks indicate that in western German states human capital and physical capital are

relatively more productive than in eastern German states. In general, the former East German states have higher-ranking production factor shares, while their output ranks are lower. The enduring migration of eastern Germans to western Germany reflects the imbalance between the eastern German human capital and output shares, caused by the productivity and wage differentials between eastern and western German states.

**Table 5.7**: Development of the Share Ranks

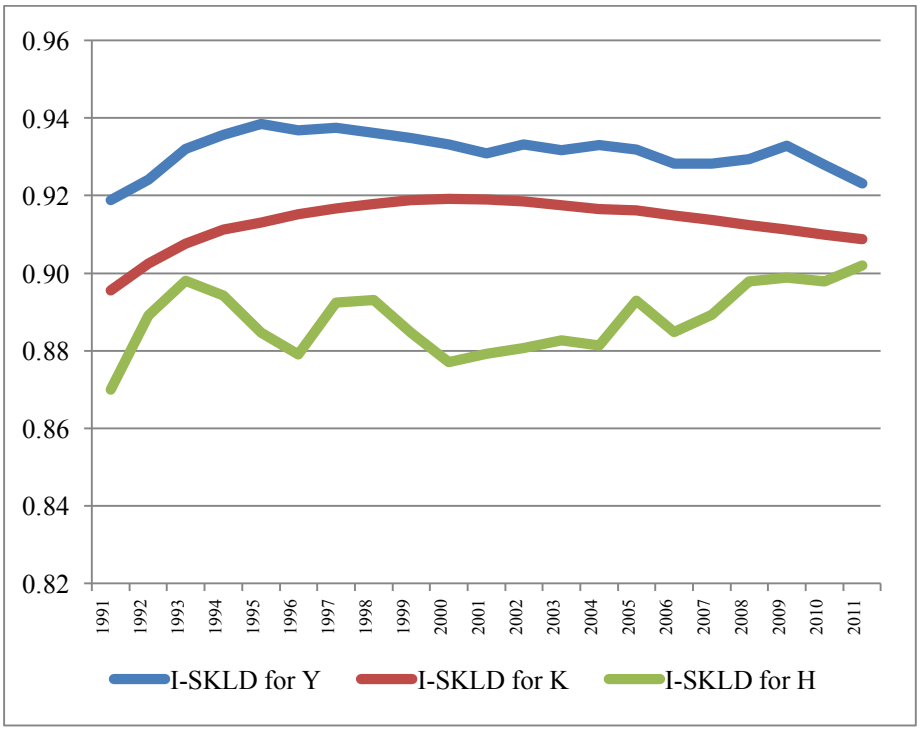
| | 1991 | | | 2011 | | |
|---|---|---|---|---|---|---|
| | Output | Physical Capital | Human Capital | Output | Physical Capital | Human Capital |
| Baden-Württemberg | 3 | 3 | 3 | 3 | 3 | 3 |
| Bayern | 2 | 2 | 2 | 2 | 2 | 2 |
| Berlin | 7 | 7 | 7 | 7 | 8 | 7 |
| Brandenburg* | 12 | 14 | 9 | 11 | 11 | 9 |
| Bremen | 15 | 16 | 16 | 16 | 16 | 16 |
| Hamburg | 8 | 9 | 14 | 8 | 10 | 13 |
| Hessen | 4 | 5 | 6 | 4 | 5 | 5 |
| Mecklenburg-Vorpommern* | 16 | 15 | 12 | 14 | 14 | 14 |
| Niedersachsen | 5 | 4 | 5 | 5 | 4 | 4 |
| Nordrhein-Westfalen | 1 | 1 | 1 | 1 | 1 | 1 |
| Rheinland-Pfalz | 6 | 6 | 11 | 6 | 6 | 8 |
| Saarland | 13 | 11 | 15 | 15 | 15 | 15 |
| Sachsen* | 10 | 10 | 4 | 9 | 7 | 6 |
| Sachsen-Anhalt* | 11 | 12 | 8 | 12 | 12 | 11 |
| Schleswig-Holstein | 9 | 8 | 13 | 10 | 9 | 12 |
| Thüringen* | 14 | 13 | 10 | 13 | 13 | 10 |

Note: Former East German states, with the exception of Berlin (former East- and West-Berlin combined), are denoted with *.

A Zipf's Law distribution of output and production factors, which depends only on the number of states, is the expected end-result of complete economic integration of the German states. This would imply that the distance between the theoretical distribution and actual distribution of shares is zero and an integration measure (ISKLD) of 1. As is show in Figure 5.1, the ISKLD is slightly above 0.91 in 2011. The ISKLD quantifies the distance between the arithmetic average of output, physical capital and human capital and the postulated distribution. To investigate which of the three is the furthest away from this distribution, SKLD is now used to assess the occurrence of Zipf's Law per variable, instead of the arithmetic average (equation 5.2). The inverted results per variable are plotted in Figure 5.2 (Kullback and Leibler, 1951).

(5.2) $$SKLD\ (\bar{S}, S_t) = \sum_{m=1}^{M} (\bar{S}_m - S_m) \ln\left(\frac{\bar{S}_m}{S_m}\right)$$

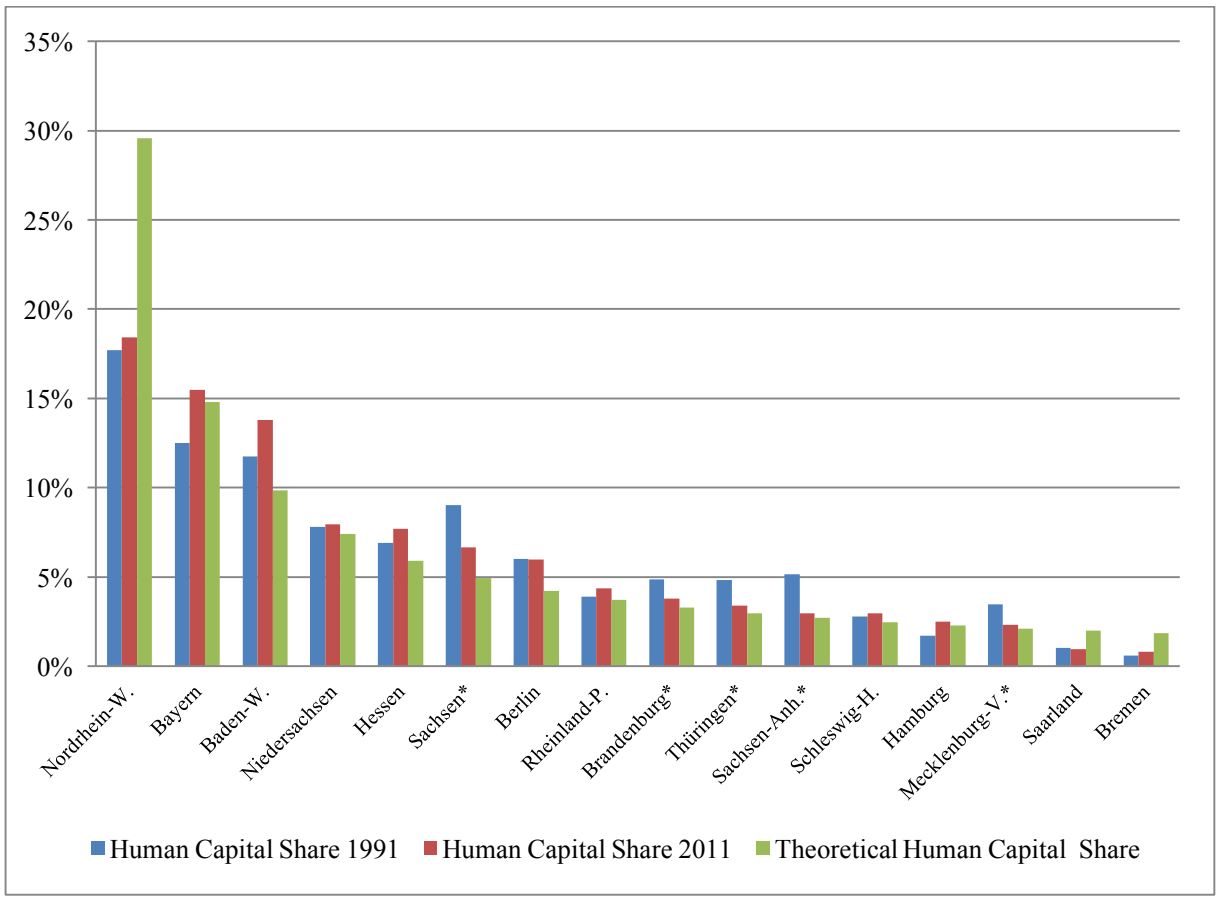
**Figure 5.2**: ISKLD for output, physical capital, human capital




Over time, the output distribution pattern is the closest to a Zipf's Law distribution, while human capital is relatively the furthest away from such a distribution. However, from 1995 onwards the distance between the observed and expected output distribution slowly increased, with acceleration after 2009. This pattern is also visible for physical capital, showing a slow decrease of the ISKLD since 1999. This reverse in trend could be the result of the termination of the Development Area Law (Fördergebietsgesetz), which provided for extra capital depreciation possibilities to companies in eastern Germany from 1991 to 1998. Contrasting is the development of the human capital distribution over time, which became more Zipf's Law distributed, even though it runs less smoothly than output and physical capital. The opposing directions in which the distributions of output and human capital move is resulting in the stagnation of economic integration of Germany since 2000 (Figure 5.1). Even though human capital made the most progress, it still has the lowest ISKLD value of the three and therefore has the most potential to improve.

Figure 5.3 shows the human capital distribution per state in 1991 and 2011 against the theoretical predicted one. During this period the human capital share of the former East German states decreased drastically, as can also be seen in Table 5.7. A further redistribution of human capital across Germany is expected, with a Zipf's Law distribution as the end result. Since this postulated distribution is the end-result of complete economic integration, it is not possible to make any prediction on future ranks of specific federal states within this distribution. Hence, it is possible that states will have different ranks in the future.

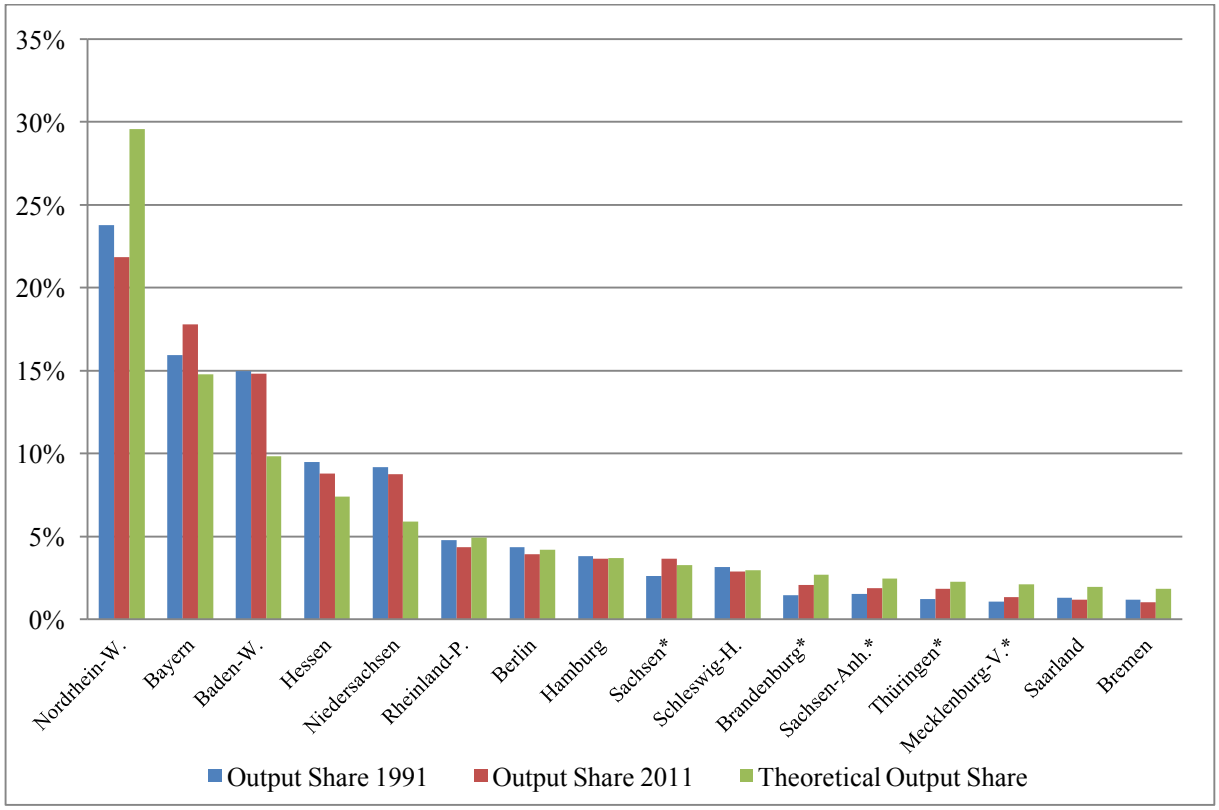
**Figure 5.3**: Human capital distribution per state




Note: Former East German states, with the exception of Berlin (former East- and West-Berlin combined), are denoted with *.

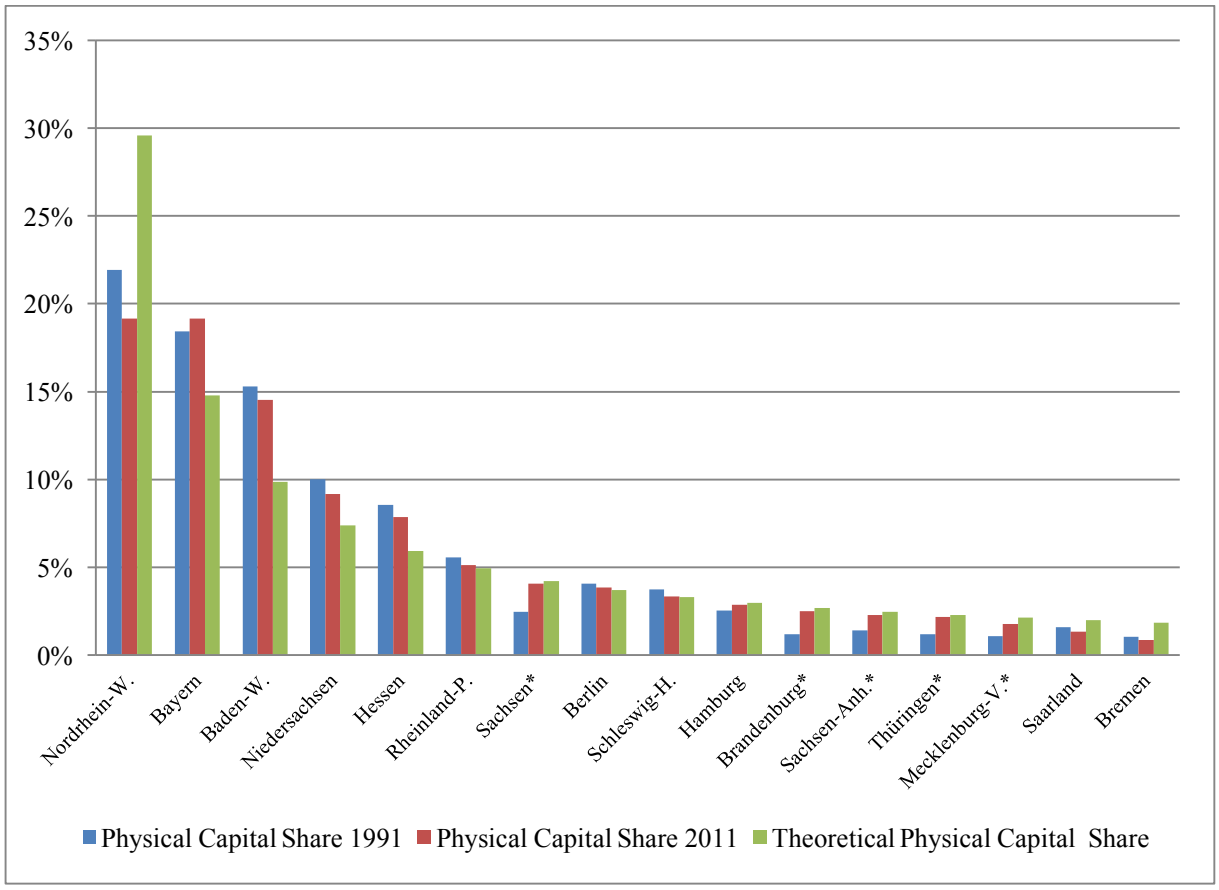
The further distribution of human capital across the German federal states is a dynamic process, it will also affect distribution of output and that of physical capital. When human capital flows from one state to the other, the marginal products of capital between states will also change and investments will again flow to the states where the marginal products are highest. Figure 5.4 and 5.5 show the distribution pattern of output and physical capital across the German states for 1991 and 2011, against the theoretical prediction. Both figures show that both output and physical capital do not completely follow the predicted distribution. A striking observation in the distribution of physical capital is that Bayern's share of physical capital is almost as large as that of Nordrhein-Westfalen's. Depending on future developments, it could be the case that in the long run Bayern could overtake Nordrhein-Westfalen's position as biggest economical state of Germany. As was the case for the human capital distribution, also here it is possible that states will have different ranks in the future.

**Figure 5.4**: Output distribution per state




Note: Former East German states, with the exception of Berlin (former East- and West-Berlin combined), are denoted with *.

**Figure 5.5**: Physical capital distribution per state




Note: Former East German states, with the exception of Berlin (former East- and West-Berlin combined), are denoted with *.

## 5.6 Future Inner-German Migration and Policy Recommendations

Since most improvements in the distribution pattern can be made within human capital, a more detailed examination is accounted for. Table 5.8 provides a summary of how current (2014) human capital within Germany would have to be redistributed in order to achieve a Zipf's Law distribution. The second column of this table contains the current human capital stocks per federal state, while the third column shows what the theoretical distribution would look like.

**Table 5.8**: Predicted Further Redistribution of Human Capital Stocks

| Federal States | Human Capital Stocks | Zipf's Law Distributed Human Capital Stock | Population with Tertiary Education | Implied In/out-Flow of Human Capital | Population per Federal State |
|---|---|---|---|---|---|
| Nordrhein-Westfalen | 3,156,000 | 4,988,569 | 17.89% | 1,832,569 | 17,638,098 |
| Bayern | 2,737,000 | 2,494,285 | 21.57% | -242,715 | 12,691,568 |
| Baden-Württemberg | 2,358,000 | 1,662,856 | 22.00% | -695,144 | 10,716,644 |
| Niedersachsen | 1,345,000 | 1,247,142 | 17.18% | -97,858 | 7,826,739 |
| Hessen | 1,299,000 | 997,714 | 21.32% | -301,286 | 6,093,888 |
| Sachsen* | 1,073,000 | 831,428 | 26.46% | -241,572 | 4,055,274 |
| Berlin | 968,000 | 712,653 | 24.13% | -255,347 | 4,011,582 |
| Rheinland-Pfalz | 748,000 | 623,571 | 21.56% | -124,429 | 3,469,849 |
| Brandenburg* | 611,000 | 554,285 | 21.58% | -56,715 | 2,830,864 |
| Thüringen* | 530,000 | 498,857 | 21.56% | -31,143 | 2,457,872 |
| Schleswig-Holstein | 510,000 | 453,506 | 22.81% | -56,494 | 2,235,548 |
| Sachsen-Anhalt* | 475,000 | 415,714 | 22.02% | -59,286 | 2,156,759 |
| Hamburg | 428,000 | 383,736 | 24.28% | -44,264 | 1,762,791 |
| Mecklenburg-Vorpommern* | 357,000 | 356,326 | 22.32% | -674 | 1,599,138 |
| Saarland | 146,000 | 332,571 | 14.76% | 186,571 | 989,035 |
| Bremen | 124,000 | 311,786 | 18.73% | 187,786 | 661,888 |
| Germany (total) | 16,865,000 | 16,865,000 | 20.77% | 0 | 81,197,537 |
| ISKLD of Human Capital Distribution | 0.904 | 1.00 | | | |

Note: Former East German states, with the exception of Berlin (former East- and West-Berlin combined), are denoted with *.

The fifth column contains the implied in- or outflow that is needed to acquire the theoretically expected distribution pattern. To get such a distribution, 2,206,926 people with tertiary education will have to migrate within Germany. This number can be computed by adding up all the positive integers of the fifth column. Almost all of them will have to migrate to the state of Nordrhein-Westfalen. The rest of the federal states, with the exception of Saarland and Bremen, will experience a decline in their human capital stock when redistributing human capital. This specific prediction can be mainly attributed to Nordrhein-Westfalen's relatively low human capital share.

One reason why Nordrhein-Westfalen, Saarland and Bremen are net-receivers of human capital is because the percentage of their population with tertiary education is well below Germany's average. This relative underperformance of Nordrhein-Westfalen is rather striking since the Ruhr region, historically the main economic region of Germany and Europe, is based in this state. For years this region is suffering from the decline of the traditional coal and steel industry and is currently running up debt to honour their part of the current Solidarity Pact (Solidarpakt II), in providing transfers to Eastern German states. This structure of subsidizing eastern German states has put great pressure on the economies of the western German states and on that of Nordrhein-Westfalen in particular, since it is experiencing a transition of its economy (Dörries, 2012). My recommendation for Germany therefore would be to increase focus on the economies of the western states and on the problems of experienced by Nordrhein-Westfalen in it's transition from a heavy industry economy to a modern innovation based one and to increase education subsidies.

The emphasis on education in the eastern German states is potentially spurring the continuous East-West migration of higher educated instead of curbing it. The eastern German states are still relatively much more human capital endowed than their western counterparts, the percentage of population with tertiary education is well above the national average of 20.77%. This is driving the constant need for the redistribution of human capital within Germany. A Zipf's law distribution is the end-result for a fully IEA where policies should be harmonized. Implementation of harmonized policies is simplified through the establishment of common goals. The question is to what degree the contemporary policies of the federal states are harmonized. The current German state is much more federalized than for instance Weimar-Germany was. The policies of the nineties were mostly characterized by western German states transferring funds to eastern German states in order to develop their economies. A sizable part of those funds is invested in the already superlative educational system of the former East German states, instead of achieving common policy targets in this area.

To assess whether a common education policy target would have resulted in a more optimal distribution of human capital, I have computed a hypothetical human capital distribution where all federal states had the relatively same amount of tertiary educated, the national average of 20.77% in Table 5.9. Compared to the current human capital distribution, the difference between this hypothetical distribution and the theoretical prediction is smaller, the ISKLD is now much higher: 0.943 against 0.904. To achieve a full Zipf's Law distribution

from here onwards, 1,668,310 people will have to migrate internally, which is 538,616 less compared to the current distribution. When policies would have been harmonized to achieve equal percentages of tertiary educated, the distribution of human capital would improve drastically. The continuous East-West migration of higher educated eastern Germans is caused by the imbalance between the relative higher levels of tertiary educated in eastern Germany, which could be reduced through policy harmonization

**Table 5.9**: Distribution of Human Capital when Based on the National Average

| Federal States | 2014 Human Capital Stocks According to the National Average | Zipf's Law Distributed Human Capital Stock | Percentage of population with Tertiary Education | Implied In/out-Flow of Human Capital | Change in Flow per Federal State |
|---|---|---|---|---|---|
| Nordrhein-Westfalen | 3,663,491 | 4,988,568 | 20.77% | 1,325,077 | -507,492 |
| Bayern | 2,636,081 | 2,494,284 | 20.77% | -141,796 | -100,919 |
| Baden-Württemberg | 2,225,882 | 1,662,856 | 20.77% | -563,026 | -132,117 |
| Niedersachsen | 1,625,640 | 1,247,142 | 20.77% | -378,497 | 280,640 |
| Hessen | 1,265,721 | 997,714 | 20.77% | -268,007 | -33,279 |
| Sachsen | 842,294 | 831,428 | 20.77% | -10,866 | -230,706 |
| Berlin | 833,219 | 712,653 | 20.77% | -120,566 | -134,781 |
| Rheinland-Pfalz | 720,699 | 623,571 | 20.77% | -97,128 | -27,301 |
| Brandenburg | 587,980 | 554,285 | 20.77% | -33,694 | -23,020 |
| Thüringen | 510,508 | 498,857 | 20.77% | -11,651 | -19,492 |
| Schleswig-Holstein | 464,331 | 453,506 | 20.77% | -10,825 | -45,669 |
| Sachsen-Anhalt | 447,966 | 415,714 | 20.77% | -32,252 | -27,034 |
| Hamburg | 366,138 | 383,736 | 20.77% | 17,599 | -26,665 |
| Mecklenburg-Vorpommern | 332,146 | 356,326 | 20.77% | 24,180 | 23,507 |
| Saarland | 205,426 | 332,571 | 20.77% | 127,145 | -59,426 |
| Bremen | 137,476 | 311,786 | 20.77% | 174,309 | -13,476 |
| Germany (total) | 16,864,996 | 16,864,996 | 20.77% | 0 | -538,616 |
| ISKLD of Human Capital Distribution | 0.943 | 1 | | | |

Note: Former East German states, with the exception of Berlin (former East- and West-Berlin combined), are denoted with *.

Besides Nordrhein-Westfalen, also Saarland and Bremen will be net-receivers of human capital (see Table 5.8). According to these theoretical predictions, the human capital stocks of the two least populous German states will have to double in size. The magnitude of these unrealistic implied inflows justifies a closer look at these two states in order to deduce potential alternative explanations that cause the produced results.

The Free Hanseatic City of Bremen consists of the two separated cities of Bremen and Bremerhaven which form two enclaves within the state of Niedersachsen (see appendix Map A.2). The survival of Bremen as an independent state is the direct result of the desire of the United States to have a North-Sea harbour included in their occupational zone after the Second World War (see appendix map A.3). In the last decade Bremen has proven that it is not economically self-sustainable and consequently a union with the surrounding state of Niedersachsen is discussed and is therefore deemed realistic (Wallbaum, 2015). Besides the accidental nature of Bremen's existence and economical unsustainability, another reason to merge it with Niedersachsen is because the political division is so heavily contrasted by the economical and sociographical intertwinement of Bremen with its surroundings. For instance, 42% of the jobs in Bremen is fulfilled by 128,000 commuters from Niedersachsen (Hotze, 2015). Taking this all into account there seems no reason whatsoever to maintain a politically independent city state that consists out of two enclaves.

Before the creation of Saarland in 1920, a comparable administrative unit or a cohesive feeling of togetherness had never existed. Saarland is one result of the Treaty of Versailles in 1919 and was an attempt by France to draw the region closer to itself. It was occupied by the United Kingdom and France under a mandate of the League of Nations. In the plebiscite of 1935 the choices between maintaining the status quo, unify with France or reunify with Germany, were given to the people of Saarland and an overwhelmingly majority voted for a reunification with Germany. After the Second World War Saarland was again occupied by France and another referendum was held in 1955, followed by the reunification of Saarland with West-Germany in 1957 (Behringer and Clemens, 2009). A merger between Saarland and Rheinland-Pfalz has seriously been debated in recent years since Saarland's fiscal position deteriorated dramatically (Caspari, 2015). Both states would be able to spend less through synergy effects, even though the number of commuters and interdependence between both states is lower than between Bremen and Niedersachsen. Nevertheless, the remarkable history of Saarland resulted in a distinct own cultural self-consciousness, making a potential merger with the surrounding Rheinland-Pfalz (see appendix Map A.2) more difficult than merging Bremen and Niedersachsen would be (Behringer and Clemens, 2009).

Because of the remarkable results and the contemporary discussions around federal state restructuring, I empirically examined what the effects would be on the statistical human capital distribution within Germany when Bremen would be incorporated in Niedersachsen

and when Saarland would be merged with Rheinland-Pfalz. A change in the number of states implies that the shares of the theoretical distribution would also change, since they uniquely depend on the number of member states.

**Table 5.10**: Theoretical Share Values

| Economic Group | Theoretical Share Values (Descending) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 15 German Federal States | 0.3014 | 0.1507 | 0.1005 | 0.0753 | 0.0603 | 0.0502 | 0.0431 | 0.0377 |
| | 0.0335 | 0.0301 | 0.0274 | 0.0251 | 0.0232 | 0.0215 | 0.0201 | |
| 14 German Federal States | 0.3075 | 0.1538 | 0.1025 | 0.0769 | 0.0615 | 0.0513 | 0.0439 | 0.0384 |
| | 0.0342 | 0.0308 | 0.0280 | 0.0256 | 0.0237 | 0.0220 | | |

The effects of these hypothetical merger on the distribution and theoretically predicted distribution patterns are summarized in Table 5.11 and Table 5.12. When Bremen would be included in Niedersachsen the distance between the actual and predicted share distribution will decrease and the ISKLD will increase from 0.904 to 0.911.

**Table 5.11**: Distribution of Human Capital after one Merger

| Federal States | 2014 Human Captial Stock | Zipf's Law Distributed Human Capital Stock | Percentage of population with Tertiary Education | Implied In/out-Flow of Human Capital | Population per Federal State |
|---|---|---|---|---|---|
| Nordrhein-Westfalen | 3,156,000 | 5,082,530 | 17.89% | 1,926,530 | 17,638,098 |
| Bayern | 2,737,000 | 2,541,265 | 21.57% | -195,735 | 12,691,568 |
| Baden-Württemberg | 2,358,000 | 1,694,177 | 22.00% | -663,823 | 10,716,644 |
| Niedersachsen and Bremen | 1,469,000 | 1,270,633 | 17.31% | -198,367 | 8,488,627 |
| Hessen | 1,299,000 | 1,016,506 | 21.32% | -282,494 | 6,093,888 |
| Sachsen* | 1,073,000 | 847,088 | 26.46% | -225,912 | 4,055,274 |
| Berlin | 968,000 | 726,076 | 24.13% | -241,924 | 4,011,582 |
| Rheinland-Pfalz | 748,000 | 635,316 | 21.56% | -112,684 | 3,469,849 |
| Brandenburg* | 611,000 | 564,726 | 21.58% | -46,274 | 2,830,864 |
| Thüringen* | 530,000 | 508,253 | 21.56% | -21,747 | 2,457,872 |
| Schleswig-Holstein | 510,000 | 462,048 | 22.81% | -47,952 | 2,235,548 |
| Sachsen-Anhalt* | 475,000 | 423,544 | 22.02% | -51,456 | 2,156,759 |
| Hamburg | 428,000 | 390,964 | 24.28% | -37,036 | 1,762,791 |
| Mecklenburg-Vorpommern* | 357,000 | 363,038 | 22.32% | 6,038 | 1,599,138 |
| Saarland | 146,000 | 338,835 | 14.76% | 192,835 | 989,035 |
| Germany (total) | 16,865,000 | 16,865,000 | 20.77% | 0 | 81,197,537 |
| ISKLD of Human Capital Distribution | 0.911 | 1.00 | | | |

Note: Former East German states, with the exception of Berlin (former East- and West-Berlin combined), are denoted with *.

If, after that, Saarland would be incorporated in Rheinand-Pfalz, the measure would increase from 9.11 to 0.916. The dissolution of two smallest German states will empirically lead to a distribution of human capital in Germany that is closer to what is theoretically expected. The computed result is rather artificial, but so was the creation of the federal states after the Second World War. Therefore, a further discussion of the proposed mergers should be seriously considered

**Table 5.12**: Distribution of Human Capital after two Mergers

| Federal States | 2014 Human Capital Stock | Zipf's Law Distributed Human Capital Stock | Percentage of population with Tertiary Education | Implied In/out-Flow of Human Capital | Population per Federal State |
|---|---|---|---|---|---|
| Nordrhein-Westfalen | 3,156,000 | 5,186,737 | 17.89% | 2,030,737 | 17,638,098 |
| Bayern | 2,737,000 | 2,593,369 | 21.57% | -143,631 | 12,691,568 |
| Baden-Württemberg | 2,358,000 | 1,728,912 | 22.00% | -629,088 | 10,716,644 |
| Niedersachsen and Bremen | 1,469,000 | 1,296,684 | 17.31% | -172,316 | 8,488,627 |
| Hessen | 1,299,000 | 1,037,347 | 21.32% | -261,653 | 6,093,888 |
| Sachsen | 1,073,000 | 864,456 | 26.46% | -208,544 | 4,055,274 |
| Berlin | 968,000 | 740,962 | 24.13% | -227,038 | 4,011,582 |
| Rheinland-Pfalz and Saarland | 894,000 | 648,342 | 20.05% | -245,658 | 4,458,884 |
| Brandenburg | 611,000 | 576,304 | 21.58% | -34,696 | 2,830,864 |
| Thüringen | 530,000 | 518,674 | 21.56% | -11,326 | 2,457,872 |
| Schleswig-Holstein | 510,000 | 471,522 | 22.81% | -38,478 | 2,235,548 |
| Sachsen-Anhalt | 475,000 | 432,228 | 22.02% | -42,772 | 2,156,759 |
| Hamburg | 428,000 | 398,980 | 24.28% | -29,020 | 1,762,791 |
| Mecklenburg-Vorpommern | 357,000 | 370,481 | 22.32% | 13,481 | 1,599,138 |
| Germany (total) | 16,865,000 | 16,865,000 | 20.77% | 0 | 81,197,537 |
| ISKLD of Human Capital Distribution | 0.916 | 1.00 | | | |

Note: Former East German states, with the exception of Berlin (former East- and West-Berlin combined), are denoted with *.

# 6. Conclusion

This thesis measured the degree of economic integration of the reunified German states during the period between 1991 and 2011, by using the statistical method developed by Bowen, Munandar and Viaene. This approach is based on a set of theoretical predictions with respect to the distribution of output and production factors across the member states of an integrated economic area (IEA), where there are no barriers to goods and factor movements and policies are harmonized.

Empirical tests of the equal-share relationship indicate an improvement over the covered time period, especially with respect to the redistribution of the production factors. However, the equal-share relationship between human capital and both output and physical capital is not as profound as between output and physical capital. Generally, the former East German states have higher-ranking production factor shares, while their output ranks are lower. The enduring migration of eastern Germans to western Germany reflects the imbalance between the eastern German human capital and output shares, caused by the productivity and wage differentials between eastern and western German states. The distribution output and physical capital follow the harmonic series we would expect within a fully IEA. Statistically, the distributions of all variables exhibit Zipf's law, but relative to output and physical capital, the distribution human capital is the furthest away from the theoretical expected one. As was the case with the equal-share relationship, the distribution of human capital improved the most over the covered time period. The postulated integration measure indicated that Germany became more economically integrated between 1991 and 2011, even though integration stagnated since 1999. The sudden decline after 2009 suggests that the great recession of 2007-2009 negatively influences the economic integration of Germany.

The emphasis on education in the eastern German states is potentially spurring the continuous East-West migration of higher educated instead of curbing it. The policies of the nineties were mostly characterized by western German states transferring funds to eastern German states in order to develop their economies. A sizable part of those funds were invested in the already superlative educational system of the former East German states instead of achieving common policy targets in this area. This structure of subsidizing eastern German states has put large pressure on the economies of the western German states and on that of Nordrhein-Westfalen

in particular. To assess whether a common education policy target would have resulted in a more optimal distribution of human capital, I have computed a hypothetical human capital distribution where all federal states have relatively the same human capital stock. When policies would have been harmonized to achieve equal percentages of tertiary educated, the distribution of human capital would improve drastically. Therefore, the continuous East-West migration of higher educated eastern Germans could be reduced through policy harmonization with respect to education. According to these theoretical predictions, the human capital stocks of the two least populous German states will have to double in size. Because of the remarkable results and the contemporary discussions around federal state restructuring, I empirically examined what the effects would be on the statistical human capital distribution within Germany if Bremen would be incorporated in Niedersachsen and Saarland would be merged with Rheinland-Pfalz. Dissolution of two smallest German states will lead to a distribution of human capital in Germany that is closer to what is theoretically expected.

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# Appendix: Data Methods, Sources and Maps of Germany

In this research paper the Bowen-Munandar-Viaene method to measure economic integration in an IEA is applied to measure the economic integration of the 16 federal German states for the years 1991 until 2011. To apply this method data for output, the physical capital stock and the human capital stock were needed for the 16 federal states for the 20 years between 1991 and 2011.

## Output

Total output of each federal state is measured by real gross domestic product (GDP) with base year 2005. The data for real GDP (Bruttoinlandsprodukt, preisbereinigt) on federal state level is provided on the website of the Working Group Regional Accounts (Volkswirstschaftliche Gesammtrechnungen der Länder). This working group consists of the States' Offices of Statistics of the 16 federal states (Statistischen Ämter) and the Federal Office of Statistics (Statistische Bundesamt). All calculations of the Regional Accounts are based on the European System of National and Regional Accounts (ESA 2010).

## Physical Capital

The physical stock of each federal state is measured by the real gross stock of fixed assets (Bruttoanlagevermögen, preisbereinigt). This data, with base year 2005, is provided on the website of the working group Regional Accounts. There is no data for the new federal states without Berlin (neue Bundesländer ohne Berlin) for the real gross stock of fixed assets in the years 1991, 1992, 1993 and 1994 on federal state level. The five new states without Berlin are: Brandenburg, Mecklenburg-Vorpommern, Sachsen-Anhalt, Sachsen and Thüringen. This is because East Germany had a different administrative division before the reunification. This is why only data for the real gross stock of fixed assets of these five states exists only on an aggregate level for the years 1991-1994. The four missing years for these states are interpolated from the available data of the years 1995-2011 per state. As control method the aggregate of these estimations has been compared to the available data of the aggregate real gross stock of fixed assets of the new federal states without Berlin for the years 1991-1994. The use of a polynomial of the second degree per federal state gave the best fitting results. The estimate capital stocks are presented in Table A.1, the aggregation of the estimations against the actual aggregate data is presented in Table A.1.

**Figure A.1**: Aggregated capital stock estimations in million euros for the new federal states without Berlin.

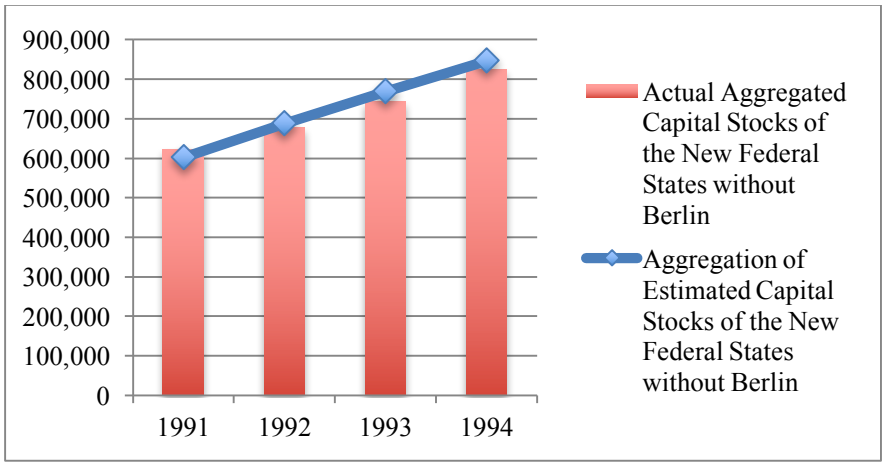



**Table A.1**: Estimated Physical Capital Stocks in Million Euros

| | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|
| Brandenburg | 98,356.67 | 116,609.52 | 134,017.63 | 150,581 |
| Mecklenburg-Vorpommern | 86,760.15 | 98,104.40 | 108,935.35 | 119,253 |
| Sachsen | 202,797.74 | 228,547.44 | 253,104.86 | 276,470 |
| Sachsen-Anhalt | 115,626.92 | 131,574.52 | 146,689.88 | 160,973 |
| Thüringen | 98,586.49 | 112,722.44 | 126,255.61 | 139,186 |

## Human Capital

In the original research of Bowen-Munandar-Viaene the human capital stock per country consists of the number of people that have completed a form of secondary education. In this thesis, the human capital stock per federal state consists of the number of people that have completed tertiary education. The levels of education offered in Germany that classify as tertiary education correspond to the International Standard Classification of Education (ISCE-97) (Statistische Ämter des Bundes und der Länder, 2014). The actual numbers of people per state that have completed tertiary education are constructed by using the data from the micro-censuses that are conducted by the statistical offices of each federal state. The statistical offices distribute their questionnaires by randomly selecting 1% of the population per state (Statistische Ämter des Bundes und der Länder, 2013). Multiplying the respondents that have completed tertiary education with 1,000 gives an approximation of the number of people per state that has completed tertiary education, our human capital stock proxy. Results of these censuses for the years 2005 till 2011 are freely available on the website of the German federal office of statistics (GENESIS-online Datenbank). The Federal Office of Statistics only

publishes results of these censuses for the years 1991 till 2004 on an aggregate level and had, for those years, no readily available data on state levels.

**Table A.2**: Number of people per federal state that have completed tertiary education 1991-2004.

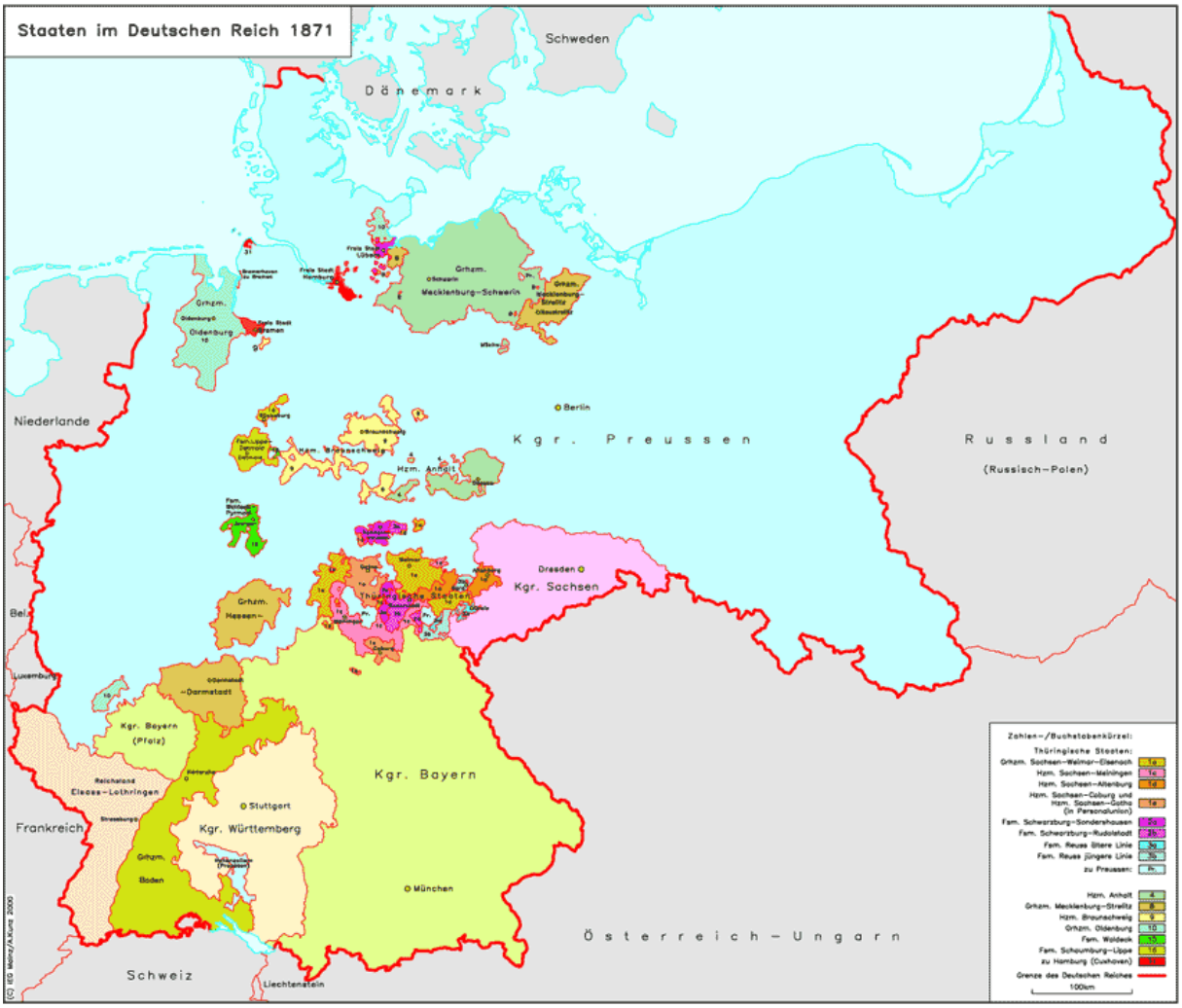
| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baden-Württemberg | 1,173,600 | | | | 1,390,000 | | 1,501,000 | | 1,547,000 | 1,560,000 | | | | |
| Bayern | 1,247,000 | | 1,320,200 | | 1,548,000 | | 1,642,000 | | 1,629,000 | | | 1,729,000 | 1,739,000 | 1,779,000 |
| Berlin | 601,000 | | 636,800 | | 708,000 | | 737,000 | | 741,000 | | 724,700 | | | |
| Brandenburg | 486,200 | | 420,800 | | 479,000 | | 514,000 | | 524,000 | | 523,100 | | | |
| Bremen | 62,400 | | | | 73,000 | | 83,000 | | 70,000 | | | | | |
| Hamburg | 168,600 | | | | 222,000 | | 236,000 | | 241,000 | | | | 252,000 | 272,000 |
| Hessen | 688,700 | | 748,000 | | 830,000 | 863,600 | 889,000 | 898,400 | 884,000 | 903,700 | 911,100 | 938,300 | 968,200 | 981,800 |
| Mecklenburg-Vorpommern | 344,500 | | 301,900 | | 358,000 | | 346,000 | | 333,000 | | 329,000 | | 335,700 | |
| Niedersachsen | 778,900 | | | | 874,000 | | 960,000 | | 940,000 | 941,700 | 920,500 | 947,100 | 980,300 | 1,030,400 |
| Nordrhein-Westfalen | 1,764,900 | | | | 2,038,000 | 2,022,000 | 2,214,000 | 2,262,000 | 2,183,000 | 2,135,000 | 2,177,000 | 2,239,000 | 2,307,000 | 2,310,000 |
| Rheinland-Pfalz | 389,400 | | 430,700 | | 455,000 | | 489,000 | | 494,000 | | | | | |
| Saarland | 101,000 | | | | 113,000 | | 116,000 | | 110,000 | | | | 118,900 | |
| Sachsen | 899,800 | | 782,700 | | 898,000 | | 897,000 | | 906,000 | | | | 928,200 | |
| Sachsen-Anhalt | 512,800 | | 446,600 | | 493,000 | 488,200 | 494,000 | 503,200 | 523,000 | 544,300 | 535,200 | 530,500 | 501,800 | 455,500 |
| Schleswig-Holstein | 276,500 | | 298,300 | | 329,000 | | 350,000 | | 357,000 | | | | 379,000 | 386,000 |
| Thüringen | 481,100 | | 421,900 | | 480,000 | 461,700 | 484,000 | 477,300 | 454,000 | 467,000 | 465,800 | 457,300 | 462,700 | 464,300 |

**Table A.3**: Number of people per federal state that have completed tertiary education 1991-2004 after interpolation.

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baden-Württemberg | 1,173,600 | 1,224,864 | 1,277,263 | 1,331,930 | 1,390,000 | 1,450,121 | 1,501,000 | 1,532,242 | 1,547,000 | 1,560,000 | 1,605,877 | 1,676,093 | 1,749,271 | 1,804,032 |
| Bayern | 1,247,000 | 1,265,378 | 1,320,200 | 1,430,792 | 1,548,000 | 1,618,653 | 1,642,000 | 1,634,494 | 1,629,000 | 1,652,662 | 1,693,322 | 1,729,000 | 1,739,000 | 1,779,000 |
| Berlin | 601,000 | 614,307 | 636,800 | 672,904 | 708,000 | 727,629 | 737,000 | 743,182 | 741,000 | 727,983 | 724,700 | 749,788 | 791,097 | 828,783 |
| Brandenburg | 486,200 | 440,591 | 420,800 | 442,278 | 479,000 | 502,247 | 514,000 | 521,707 | 524,000 | 520,435 | 523,100 | 542,065 | 566,812 | 581,679 |
| Bremen | 62,400 | 63,227 | 64,783 | 67,797 | 73,000 | 79,884 | 83,000 | 78,014 | 70,000 | 65,071 | 64,100 | 66,646 | 72,271 | 80,535 |
| Hamburg | 168,600 | 183,755 | 198,188 | 211,177 | 222,000 | 230,152 | 236,000 | 239,863 | 241,000 | 239,247 | 237,802 | 240,706 | 252,000 | 272,000 |
| Hessen | 688,700 | 715,610 | 748,000 | 788,707 | 830,000 | 863,600 | 889,000 | 898,400 | 884,000 | 903,700 | 911,100 | 938,300 | 968,200 | 981,800 |
| Mecklenburg-Vorpommern | 344,500 | 311,466 | 301,900 | 328,141 | 358,000 | 359,496 | 346,000 | 337,237 | 333,000 | 329,556 | 329,000 | 333,003 | 335,700 | 332,569 |
| Niedersachsen | 778,900 | 790,959 | 807,705 | 833,823 | 874,000 | 926,012 | 960,000 | 953,340 | 940,000 | 941,700 | 920,500 | 947,100 | 980,300 | 1,030,400 |
| Nordrhein-Westfalen | 1,764,900 | 1,890,151 | 1,992,612 | 2,049,492 | 2,038,000 | 2,022,000 | 2,214,000 | 2,262,000 | 2,183,000 | 2,135,000 | 2,177,000 | 2,239,000 | 2,307,000 | 2,310,000 |
| Rheinland-Pfalz | 389,400 | 412,250 | 430,700 | 442,626 | 455,000 | 473,435 | 489,000 | 493,221 | 494,000 | 500,813 | 513,059 | 527,620 | 541,376 | 551,209 |
| Saarland | 101,000 | 104,118 | 107,188 | 110,165 | 113,000 | 115,390 | 116,000 | 113,800 | 110,000 | 106,443 | 105,266 | 108,681 | 118,900 | 133,559 |
| Sachsen | 899,800 | 814,638 | 782,700 | 833,036 | 898,000 | 909,829 | 897,000 | 899,359 | 906,000 | 899,963 | 890,835 | 894,840 | 928,200 | 992,654 |
| Sachsen-Anhalt | 512,800 | 465,931 | 446,600 | 468,881 | 493,000 | 488,200 | 494,000 | 503,200 | 523,000 | 544,300 | 535,200 | 530,500 | 501,800 | 455,500 |
| Schleswig-Holstein | 276,500 | 286,351 | 298,300 | 313,461 | 329,000 | 341,606 | 350,000 | 354,151 | 357,000 | 361,446 | 367,266 | 373,453 | 379,000 | 386,000 |
| Thüringen | 481,100 | 435,167 | 421,900 | 455,962 | 480,000 | 461,700 | 484,000 | 477,300 | 454,000 | 467,000 | 465,800 | 457,300 | 462,700 | 464,300 |

To collect the results of the censuses for the years 1991 till 2004, I approached the 14 individual Offices of Statistics of the 16 states, with the request if the data for these years are still available. Since these data were produced by hand they are not available electronically and the Offices looked into the archives and sent me scans of the relevant pages. All collected received data is presented in Table A.2. The gaps for the years 1992 and 1994 are because no census was conducted during these years. All missing data points are estimated with the use in interpolation techniques. Those results are presented in Table A.3.

**Map A.1**: The German Empire 1871-1918.




Source: Server für digitale historische Karten am Leibniz Institut für Europäische Geschichte – Mainz.

**Map A.2**: Map of Present-day Germany.


Source: Server für digitale historische Karten am Leibniz Institut für Europäische Geschichte – Mainz.

**Map A.3**: Occupational Zones of Germany 1945-1949.


Source: Server für digitale historische Karten am Leibniz Institut für Europäische Geschichte – Mainz.