Long-Run Relationships as Basis of Innovation

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Preliminary version, please do not quote

Abstract

The paper tries to explain R&D efficiency differences in Germany. Cooperation between firms and public research institutions as well as location decisions of private R&D units are analyzed. This leads to the following hypothesis: the influence of engineers on production differs between northeast and southwest Germany. Empirical tests cannot reject this hypothesis but some assumptions remain to be tested.

[1]Mrs. Margrit Thiele, Statistisches Bundesamt, Wiesbaden coordinated data delivery between several departments. Mr. Fischer from Statistisches Landesamt Stuttgart delivered capital stock data. Their work was so efficient that I got some data within very small time intervals. Thank you very much! Calculations were done with 'R'. R Development Core Team (2007). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Introduction

Why is the efficiency of German regional innovation systems (RIS) so different? The region with the lowest R&D-productivity is just 9.8 percent of that of the highest one. Empirical evidence shows that RIS differ more concerning their average than their marginal productivity (Fritsch, Slavtchev, 2007, S. 18); these results were obtained by relating private R&D-input to number of patents. Spillovers could be one explanation; regions with high R&D-efficiency may be characterized by a) high rate of cooperation between private firms, b) information diffusion by job change or c) a high rate of cooperation between firms and public research institutions. Case a) was examined but the data did not support it (Fritsch, 2004).

The influence of public research institutions is according to Diez (2000) smaller than usually expected. Nevertheless public research institutions seem to be an important part of RIS (Fritsch und Schwirten, 1999). Fritsch points out that their influence might be insignificant but its influence is tremendous when significant. Hence, to explain the difference in R&D-efficiency between north-east and the rest of Germany, differences in the interplay of public research institutions and firms might be a decisive explanatory factor. Therefore this relation is theoretically disentangled and the influence of the fall of the Berlin wall is taken into account. This ends up with a simple hypothesis: the long-run interplay of production factors differs between northeast and the rest.

Engineers are here seen as the source of patents in the producing sector and their number is taken as an additional input in the traditional production function. Regions with high R&D-efficiency are supposed to have a stable long-run relationship between the real gross value added and the number of engineers, number of occupied people (working hours would be better is however not available) and capital stock. It is assumed that we observe such long-run relationships especially in West-Germany, a region with high R&D-efficiency. In the north-east, however, no such relationship is expected because a) of the dramatic changes in production and fierce international competition going back to the fall of the Berlin wall and b) a high propensity of German and foreign firms with subsidiaries in north-east to maintain their research facilities at their ancestral seats. Hence, engineers in northeast are occupied with implementation of new knowledge produced at research facilities at their ancestral seats and have thus almost no chance to announce a patent.

The empirical work is made for each federal state separately. First, the time series are checked for stationarity. As non-stationarity is detected, the degree of integration is tested. This way we get hints whether long-run relationships could exist at all and between which variables this being relevant. It shows that the long-run relationships differ between the federal states and, as supposed, we find the expected long-run relationships in the West but in the northeast other relations hold.

Some theoretically considerations are presented in the next chapter. The concept of cooperation is clarified and motives for cooperation are discussed. This leads to a very simple hypothesis: the influence of engineers on production differs between northeast and southwest Germany. The following empirical analysis is divided into two sections: univariate data analysis and co integration. According to the empirical regularities detected, the hypothesis cannot be rejected. The paper ends with few remarks concerning remaining work to be done and some economic policy consequences.

Theoretical Considerations

Cooperations

There is no universally accepted definition of cooperation. According to Fritsch (2004, p. 829) any incomplete contract leaving room for opportunistic behavior is a cooperation. Then a lot of employment contracts would have to be classified as cooperation. To exclude this, contracts between legally independent organizations providing room for opportunistic behavior are here regarded as cooperation.

Particularly co operations between public research institutions and firms are of interest. They can be analyzed on two levels: a) decision concerning establishment of a public research institution or firm and b) decision concerning cooperation between them. Decisions concerning establishment of public research institutions will not be considered explicitly. It is simply assumed and seems to be a matter of fact that they are more or less evenly distributed in Germany but the following question will be focused. Is the existence of a public research institution decisive for location decision of firms?

Answering part b) (decision about cooperation) will give us hints to answer this question. Both, public research institutions and firms, have to decide whether cooperation might be useful and if so which kind of cooperation should be preferred. Public research institutions are no homogeneous set of people; professors, researchers and students are relevant stakeholders. Professors and researchers are interested in new insights which might be financed by private firms (or public organizations). Scientific staff members and students are interested in co operations as a means to a job. To buy new ideas or knowledge not available in a firm or to get a competitive edge by highly qualified employees represent motives which induce firms to cooperate with public research institutions. Hence we should distinguish between two market segments: knowledge market and labor market.

Knowledge Market

Following cooperative research activities can be distinguished: a) public research projects financed by third-party funds, b) apprenticeship and in-service training c) diploma or master thesis in cooperation with a firm d) 'practice projects', i.e. cooperation of lecturer and his students with a firm for solving firm specific problems e) consulting of firms by researchers. At the knowledge market all these channels are possible. However, firm demand for knowledge is derived demand and thus sector- and product-specific.

To accommodate sector- and product-specific demand for knowledge, firm-specific knowledge, i.e. knowledge about firm organization, firm-intern processes and rules as well as technology in use, is decisive. To develop production processes and to sell new products successfully, market knowledge and firm-specific knowledge as well as knowledge about technically and financial possibility frontiers of competitors are decisive. Diffusion of own products is dependent on the existence of substitution and complementary goods. In other words, practical knowledge, being dispersed over a lot of employees, matters and being communicated verbally is important to get a competitive edge. This kind of knowledge, however, is for several reasons not available in public research units: first because some knowledge is kept dark or remains tacit and second as it is not freely available but costly to acquire. Hence, these knowledge differences establish an important criterion to decide whether demand for knowledge being accommodated ex- or internally.

Other rules govern public research. Here specificities of sectors or products are of no interest but universal rules being valid in a lot of circumstances are explored and taught. As prevailing circumstances of firms are usually ignored, public research institutions are not very well equipped to solve firm-specific problems. Nevertheless, one might argue that German Frauenhofer-Societies are an exception because they have to finance a fundamental part of their research efforts by third party funds. Hence they might be best characterized as a hybrid: neither firm nor public research institution. Because they form just a small part on the German research landscape, their influence is not considered further on.

The focus of public research units is universal knowledge which can be applied in several circumstances. Market singularities are of minor importance and may just serve to highlight scientific insights. To mitigate information deficits of firms and to initiate step-by-step innovations, management consultancy seems more suitable. Co operations between firms and public research institutions may however serve another aim which management consultancy is not well equipped. As they are non-profit organizations, the results of public research units may be trustworthy and thus in some circumstances being preferred.

A different matter is basic research which opens new markets. Then public research units may play an important part in market processes until firm-intern research units acquire this knowledge and market- and firm-specific knowledge carries weight. As basic research results with market relevance are singular events, cooperation between public research units and firms *because of this reason* are evaluated as singular too. Furthermore, as firms usually do not know in advance in which research unit relevant basic knowledge will be produced and in which fields basic knowledge demand arises, there is no basis to make an informed location decision. Thus we conclude that firms do have no distinct interest to locate near a specific public research institution *because of knowledge demand*. Hence, spatial planning of public basic research units has minor importance for private firms but in the rare case of basic research results opening new markets. However, even in this case firms usually implement own R&D units for adapting to market- and firm-specific circumstances. Firms may yet have an interest to locate with public research units because of their desire to attract 'high potentials' and thus labor market is focused.

Labor Market

Diploma and master thesis made in cooperation with firms have the function to arrest attention. This is true for firms and scientific staff members as well as students. Hence, they are part of personal management of a firm. Third party funds and practice projects may serve the same aim and at the same time firms influence schooling content. As transaction costs increase with distance, firms with demand for high potentials have a propensity to locate near public research institutions. Hence, we got also an answer to question a): firms producing high quality goods have a propensity to locate near public research institutions because of labor demand; knowledge demand is of minor importance.

Prevailing Circumstances

Structural Change

Our analysis of cooperation gives no hints why R&D efficiency of firms should differ so drastically between north-east and the rest. Therefore differences in their historic developments are checked because it might be that structures differ because of the fall of the Berlin wall. It is speculated that West-German structures which evolved during several decades were barely affected but structures in north-east changed quite profoundly. This might be a cause of the observed efficiency differences.

The withdrawal of German cleavage with its introduction of the German Mark in former East-Germany ended in dramatic changes. Over night East German firms faced international competition which they were not apt to. Large part of its industry went bankrupt or was bought by West-German or international investors or they built new commercial units. Answers to the following questions may help to disentangle the puzzle: a) what is the reason for the engagement in former East Germany? b) What kind of commercial units were built? c) Which effects did this have on R&D of firms and d) cooperation between them and public research units?

Question a) might be answered by traditional international economics: absolute or comparative cost-advantage, different resource availability as well as internally or externally scale economies (Krugman, Obstfeld, 2003). Structural change is measured by changing production and demand patterns as well as changing relative prices. Alternatively knowledge advantages in former East Germany might let to investments in north-east Germany. However, this explanation seems groundless because of the cause of the fall of the Berlin wall. Hence, relocation of production facilities seems to be explained best by traditional approaches. Did this, however, result in an 'export' of West-German and foreign R&D structures?

Long Run Relationships

If production units in the Newly-formed German states differ from that in rest of Germany, an explanation of R&D efficiency differences could be as follows. To implement and to run high-technology facilities, engineers are necessary both, in north-east and south-west Germany. In former East Germany they may also be involved in R&D activities but their employment is application-oriented with results not being able to grant a patent (details are to be found in § 1 paragraph 3 Patentgesetz). Their colleagues in rest of Germany being engaged in R&D whose output is patentable have thus much higher R&D efficiency. Hence, the question arises why this pattern should have emerged?

In other words: why should firms decide this way? Finding the factors which determine location decisions of R&D units of firms will give an answer. To shift in-house R&D units from a parent company to former East Germany had evoked sunk-costs because part of existing facilities and organizational structures (including co operations with public research units) had no other usage. In-house R&D units need close relationships to high-technology production processes to consider tacit knowledge won during production; and vice versa high-technology production processes need R&D to ensure high quality levels and to exploit learning curve effects. These departments are complementary which increases shifting costs.

Seen from the perspective of R&D personnel and their families, to move to former East Germany would have decreased quality of life. As employment prospects of engineers have been reasonably good since several years, a shift of R&D units would have caused terminations which would have changed existing firm structures and knowledge bases. Replacing R&D units in former West Germany by completely new ones in former East Germany had destroyed a firm's knowledge base at large part.

Furthermore, to assure a steady flow of high-quality scientific staff personnel, in former West Germany stable co operations between firms and public research units had a chance to emerge in course of time. The fall of the Berlin wall and abandonment of large parts of industrial production in former East Germany destroyed such relationships but establishment of new ones needs time. As co operations leave room for opportunistic behavior, trust is very important. But it is established slowly by good experiences and gambled away quite easy by bad ones. Hence, seen under this perspective, production in the Newly-formed German states should differ from rest of Germany.

If this explanation would be true, R&D differences are the result of decisions of parent companies located outside former East Germany to establish production units and application-oriented R&D in the Newly-formed German states . In other words, we hypothesize a qualitative difference between R&D inside and outside the Newly-formed German states . Hence, the detected differences in R&D efficiency would be the result of measuring methods. There exist several possibilities to test this explanation. Because engineers are the source of patents, a straightforward method would be to test their influence on production processes in the German Federal states. If the explanation would be true, the impact of engineers on production should be higher in southwest than in northeast Germany.

Univariate Data Analysis

The German Statistical Office provided most data. German 'Mikrozensus' is the database for 'number of engineers' in the producing sector. Up until 1998 data is just available as printed tables and additional analysis had to be done. Data sets are provided with engineers being assigned to disjunct classes 'type of engineers'; sum of all engineers is not available and is therefore calculated from the types of engineers. That led to some inaccuracy because of rounding errors in the original data set. As a consequence some Federal states could not be analyzed. As from 1999 all data is digitalized, this source of error disappeared. Number of occupied people was from GENESIS, an online service of the German Statistical Office, Wiesbaden. Capital stock was provided by the German ‚Arbeitskreis Volkswirtschaftliche Gesamtrechnungen der Länder (AK VGRdL).

Available integration tests give wrong signals in case of structure break (see Assenmacher, 2002 for details). As the German Economic Advisory Council (Sachverständigenrat) (SVR, 2003) detected a structure break in macroeconomic time series in 1993, data from 1992 – 2005 is taken to be able to build first, second and third differences. Data for 2006-2007 are in 2007 not available.

Economic time series are often non-stationary but being I (1) or I (2) integrated and this matches the present data. To avoid spurious regression, a) the degree of integration has to be tested for each time series separately and b) tests of co integration are necessary. In both cases the Dickey-Fuller Test (ADF-Test) is here used. However, if autocorrelation of residuals is present, its results are often wrong; therefore the Breusch-Godfrey-LM-Test (BG-Test) is used to get hints of the lag-structure of endogenous variables being necessary to avoid autocorrelation between residuals.

Step a) is separated into the following parts: 1. determination of the lag structure of the absolute values, its first and second differences. Based on that results ADF-Tests are made; given the ADF-Test cannot reject the Null-hypothesis of the absolute value (and hence the time series is not I (0)) but the first differences is I (0), the variable is I (1). If the ADF-Test rejects the Null-hypothesis for absolute values and its first differences but not the second ones, the time series is I(2).

Results of this univariate analysis are presented in table 1 and will be discussed step by step. The following abbreviations are used: y: real Gross Value Added, logarithmic value, x1: number of occupied people without engineers, logarithmic value, x2: number of engineers, x3: capital stock, logarithmic value.

		Baden-Württemberg			Bavaria			Hesse			Lower-Saxony			Northern-Westphalia			Rhineland-Palatine		
		absolute values	first differences	second differences	absolute values	first differences	second differences	absolute values	first differences	second differences	absolute values	first differences	second differences	absolute values	first differences	second differences	absolute values	first differences	second differences
y:	without drift			I(0)			I(0)		I(0)	I(0)		I(0)	I(0)		I(0)	I(0)		I(0)	I(0)
	with drift		I(0)			I(0)			I(0)		I(0)				I(0)			I(0)	
	with linear trend	I(0)	I(0)					I(0)			I(0)				I(0)				
x1:	without drift			I(0)			I(0)	I(0)		I(0)			I(0)			I(0)			I(0)
	with drift																		
	with linear trend																	I(0)	
x:2	without drift			I(0)			I(0)		I(0)	I(0)		I(0)	I(0)		I(0)	I(0)			I(0)
	with drift				I(0)						I(0)	I(0)							
	with linear trend										I(0)	I(0)						I(0)	
x:3	without drift		I(0)	I(0)			I(0)						I(0)						I(0)
	with drift																		
	with linear trend	I(0)																	

Table 1: Results of ADF-Tests based on BG-Tests (not shown)

Legend: I(0) means stationary process with 10 per cent probability of rejection.

y: real Gross Value Added, logarithmic value

x1: number of occupied people without engineers, logarithmic value

x2: number of engineers

x3: capital stock, logarithmic value

		SchleswigHolstein			Berlin			Brandenburg			Saxony			Saxony-Anhalt			Thuringia		
		absolute values	first differences	second differences	absolute values	first differences	second differences	absolute values	first differences	second differences	absolute values	first differences	second differences	absolute values	first differences	second differences	absolute values	first differences	second differences
y:	without drift		I(0)	I(0)	I(0)		I(0)	I(0)	I(0)	I(0)		I(0)			I(0)	I(0)			I(0)
	with drift		I(0)			I(0)			I(0)		I(0)	I(0)						I(0)	
	with linear trend								I(0)									I(0)	
x1:	without drift	I(0)		I(0)	I(0)		I(0)	I(0)		I(0)			I(0)	I(0)		I(0)	I(0)		I(0)
	with drift					I(0)		I(0)										I(0)	
	with linear trend					I(0)												I(0)	
x:2	without drift		I(0)	I(0)		I(0)	I(0)		I(0)	I(0)		I(0)	I(0)		I(0)	I(0)			I(0)
	with drift				I(0)	I(0)						I(0)							
	with linear trend					I(0)													
x:3	without drift			I(0)			I(0)			I(0)			I(0)		I(0)	I(0)			I(0)
	with drift											I(0)					I(0)		
	with linear trend													I(0)					

Table 1 (continued): Results of ADF-Tests based on BG-Tests (not shown)

Legend: I(0) means stationary process with 10 per cent probability of rejection.

y: real Gross Value Added, logarithmic value

x1: number of occupied people without engineers, logarithmic value

x2: number of engineers

x3: capital stock, logarithmic value

Baden-Württemberg: The absolute value of the dependent variable y is I (0) with linear trend and this is confirmed by its first difference with drift being I (0) too; similarly the same holds for x3. Variables x1 and x2 are I (2). Hence, estimation of a production function is possible provided that a) x1 and x2 are C (2,2), b) residuals of x1+a2*x2 with co integration vector (1,a2) is I (0) and c) y and f (x1, x2)+x3 with appropriate co integration vector is C (0,0).

Bavaria: The first difference of the dependent variable y is I (0) (with drift) and that is confirmed by the second difference which is I (0) (without drift). Thus, y is I (1). All other variables are I (2) because their second differences are I (0) without drift. Hence, a long-run relationship may hold provided x1+a2*x2+a3*x3 is I (1), y being I (1) and the residuals of y=a+ x1+a2*x2+a3*x3 being I (0).

However, according to the BG-Test (not shown) autocorrelation disappears with 4 lags, the available data allows only building third differences; therefore the ADF-Test might be wrong and y might be I (0). If however y is I (0), x1+a2*x2+a3*x3 is I (0) and residuals of y=a+ x1+a2*x2+a3*x3 are I (0), we also have a long-run relationships and in fact, this happens.

Hesse: The depended variable y is I (0) with linear trend being validated by its first difference which is I (0) with drift. X3 is not integrated of degree lower than 3 and x1 is I (2). However, x2 is I (1). In sum, no long-run relationship between all variables holds; just a relation between y and x1 might exist given they are C (1, 1).

Lower Saxony: Variables y and x2 are I (0) with drift being proved by I (0) without drift of their first differences. All other variables are I (2) without drift. Thus, if x1 and x3 are co integrated C (2, 2) and residuals of y = x2 + 1*x1+a3*x3 (with co integration vector (1, a3)) would be I (0); a long-run relationship would exist.

Northrhein-Westphalia: x1 is I (2) and no other variable does so. Hence, no long-run relationship between all variables holds. However, a long-run relationship might exist between y and x2.

Rhineland-Palatinate: y, x1 and x2 are I (1) which is proved by their second differences but x3 is I (2). Because of this, no long-run relationship between all variables exists. However, a long-run relationship might be present between y, x1 and x2 provided residuals of y= a+a1*x1+a2*x2 are I (0).

Schleswig-Holstein: y and x2 are I (1) being confirmed by its second differences; and x1 and x3 are I (2) (without drift). Hence a long-run relation might hold if x1 and x3 are co integrated C (2, 1) and residuals of y = x2 + f(x1, x3) with appropriate co integration vector being I (0).

Berlin: y and x1 are I (1) but x2 is I (0) and x3 is I (2). Hence, no long-run relationship holds between all variables but their might be such a relation between y, x1 and x2 with dependent variable x2!

Brandenburg: y is I (0), x2 is I (1) and the other variables are I (2). A long-run relationship might hold: 1*x1+a2*x3 (with integration vector (1, a2)) have to be I (1) and residuals of x2 + z1*(1*x1+a2*x3) must be I (0).

Saxony: y is I(0), x2 and x3 are I(1) and x1 is I(2) and therefore no long-run relation will hold between all variables, however, x2 and x3 as well as y, x2 and x3 might be co integrated.

Saxony-Anhalt: As x1 is I (2) but no other variable does have the same integration, no long-run relationship between all variables hold. X3 is I (0), y and x2 are I (1) and therefore a long-run relationship between these variables may exist.

Thuringia: y and x1 is I (1) and x2 and x3 is I (2) and thus a long-run relationship might be present.

Cointegration

Baden-Württemberg

Table 2 shows results of integration tests for time series with identical integration being higher than 0. The second column is the results of regression x1 on x2 for Baden-Württemberg. The BG-Test indicates no autocorrelation and the ADF-Test shows that the variables are C (2, 2). The normed integration vector is (1, 0.0017).Thus a long-run relationship may hold if the residuals of y= a + x3 + a_z*z (with z=1*x1+0.0017*x2) are I (0) and according to table 3, column 2 this happens. Thus, the long-run relationship between all variables can be estimated whose results are presented in table 4, column 2.

Assuming neutral technical change and replacing Solow's multiplicative factor A(t) by number of engineers we get the result presented in table 5, column 2 which differs from the result in table 4 just by the absolute term: in table 4 there are inhomogeneous and in table 5 homogenous regressions. The estimated coefficients of the production factors are their production elasticities because all time series besides the number of engineers are logarithmic. The elasticities of labor and capital stock sum up to 0.9956 and the influence of number of engineers is positive. The time series are stationary but nevertheless autocorrelation may be present which influences variance estimations. Thus the significant levels are not reliable.

Bavaria

Variables x1, x2 and x3 are C (2, 2) (Table 2). As the residuals of regression y on linear-combination x1-0.00073*x2-1.4158*x3 are I (0), a long-run relationship between all variables holds. Table 5 shows regression of y on all other variables. Sum of production elasticities is 0.72.

Hesse

A long-run relationship holds between y and x1, however, estimation of a *homogeneous* regression is not reliable because of the ADF-Test.

Lower-Saxony

Variables x1 and x3 are co integrated C(2,2) (table 2) and residuals of regression of y on x2 +f(x1,x2) with appropriate integration vector is I(0), thus a long-run relationship holds.

Dependent variable	x1	x1	y	x1		y
	Baden-Württem-berg	Bavaria	Hesse	Lower-Saxony	Northern-Westphalia	Rhineland-Palatine
Absolute Value	7.71***	25,14*	12,49***	-47.31***	11,83***	10,93***
x1	-	-	-0.28254 *	-	-	-0.131770
x2	-0.0017**	-0.00073	-	-	-0.00073	0,0018
x3		-1.416	-	4,582 ***	-	-
Multiple R-Squared:	0.63	0,68	0.4715,	0,82	0,26	0,52
F-statistic:	15.32 on 1 and 9 DF, p-value: 0.00354	8.46 on 2 and 8 DF, p-value: 0.01062	8.029 on 1 and 9 DF, p-value: 0.01961	42.02 on 1 and 9 DF, p-value: 0.0001138	3.085 on 1 and 9 DF, p-value: 0.1129	4.294 on 2 and 8 DF, p-value: 0.0541
BG-Test	3.0583, df = 2, p-value = 0.2167	4.118, df = 1, p-value = 0.04243	1.1827, df = 1, p-value = 0.2768	1.4763, df = 1, p-value = 0.2243	0.0563, df = 1, p-value = 0.8124	0.8302, df = 1, p-value = 0.3622
ADF-Test without drift	-1.8732 P VALUE: 0.06097	-2.5235 P VALUE: 0.01512	: -3.0359 P VALUE: 0.01	: -2.3232 P VALUE: 0.02263	: -2.6404 P VALUE: 0.01074	: -2.9615 P VALUE: 0.01

Table 2: Test of Cointegration, Part 1

Legend:

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

y: real Gross Value Added, logarithmic value

x1: number of occupied people without engineers, logarithmic value

x2: number of engineers

x3: capital stock, logarithmic value

Dependent variable	x1	y	x1	x2	y	x2
	Schleswig-Holstein	Berlin	Brandenbur g	Saxony	Saxony-Anhalt	Thuringia
Absolute Value	-19.33***	7,41***	65,96**	-919.82**	9,409693***	-508.84 *
x1	-	0,39249***	-	-	-	-
x2	-	-	-	-	-0.005077 .	-
x3	2,358***	-	-5743**	86,97**	-	51,37*
Multiple R-Squared:	0,95	0,97	0.6314,	0,61	0.3275,	0,46
F-statistic:	169.9 on 1 and 9 DF, p-value: 3.791e-07	256.3 on 1 and 9 DF, p-value: 6.398e-08	15.42 on 1 and 9 DF, p-value: 0.003477	13.83 on 1 and 9 DF, p-value: 0.004782	4.382 on 1 and 9 DF, p-value: 0.06582	7.752 on 1 and 9 DF, p-value: 0.02125
BG-Test	0.2273, df = 1, p-value = 0.6336	2.3162, df = 1, p-value = 0.1280	7.7398, df = 1, p-value = 0.005402	0.2286, df = 1, p-value = 0.6326	LM test = 0.1786, df = 1, p-value = 0.6726	LM test = 2.5967, df = 1, p-value = 0.1071
ADF-Test without drift	: -1.4069 P VALUE: 0.1613	: -3.1518 P VALUE: 0.01	: -1.8499 P VALUE: 0.0643	: -2.968 P VALUE: 0.01	: -1.6958 P VALUE: 0.08632	: -1.5517 P VALUE: 0.1153

Table 2 (continued): Test of Cointegration, Part 1
Legend:
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
y: real Gross Value Added, logarithmic value
x1: number of occupied people without engineers, logarithmic value
x2: number of engineers
x3: capital stock, logarithmic value

	Baden-Württem-berg	Bavaria	Hesse	Lower-Saxony	Northern-Westphalia	Rhineland-Palatine
Dependent Variable	y	y		y		
Absolute Value	1,03	2,39	Not possible	1,53	Not possible	not necessary
z	-1.0040 **	-0.8945 ***		0,15		
x1	-	-				
x2	-	-	-	0,004165		
x3	1,43	-		-		
Multiple R-Squared:	0,59	0,73		0,27		
F-statistic:	5.817 on 2 and 8 DF, p-value: 0.02756	24.76 on 1 and 9 DF, p-value: 0.0007633		1.477 on 2 and 8 DF, p-value: 0.2845		
BG-Test	3.8327, df = 2, p-value = 0.1471	2.2339, df = 1, p-value = 0.135		0.6469, df = 1, p-value = 0.4212		
ADF-Test without drift	-1.9051 P VALUE: 0.05641	-3.1876 P VALUE: 0.01		-2.501 P VALUE: 0.01596		

Table 3: Test of Cointegration, Part 2

Legend:

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

y: real Gross Value Added, logarithmic value

x1: number of occupied people without engineers, logarithmic value

x2: number of engineers

x3: capital stock, logarithmic value

Dependent Variable	y	x2	y	y	x3	y
	Schleswig-Holstein	Berlin	Branden-burg	Saxony	Saxony-Anhalt	Thuringia
Absolute Value	5,285**	40,97	17,73***	9,156***	16,02***	14.3514441 ***
z	0,1382257*	0,26	0,15***	0,000745	-0.58 .	-0.0005969
x1	-	-	-	-	-	- 0.8270471* **
x2	0,000706					
x3	-	-	-	-	-	-
Multiple R-Squared:	0,61	0	0,81	0,07	0,31	0,95
F-statistic:	6.309 on 2 and 8 DF, p-value: 0.02267	0.001086 on 1 and 9 DF, p-value: 0.9744	38.1 on 1 and 9 DF, p-value: 0.0001642	0.7204 on 1 and 9 DF, p-value: 0.418	3.951 on 1 and 9 DF, p-value: 0.07808	79 on 2 and 8 DF, p-value: 5.394e-06
BG-Test	0.1145, df = 1, p-value = 0.735	0.757, df = 1, p-value = 0.3843	0.1121, df = 1, p-value = 0.7377	LM test = 5.342, df = 1, p-value = 0.02082	2.3632, df = 1, p-value = 0.1242	0.0418, df = 1, p-value = 0.838
ADF-Test without drift	-2.7311 P VALUE: 0.01	-3.3859 P VALUE: 0.01	-3.359 P VALUE: 0.01	: -2.5619 P VALUE: 0.01368	-3.2573 P VALUE: 0.0976	-3.803 P VALUE: 0.01

Table 3 (continued): Test of Cointegration, Part 2

Legend:

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

y: real Gross Value Added, logarithmic value

x1: number of occupied people without engineers, logarithmic value

x2: number of engineers

x3: capital stock, logarithmic value

Northern-Westphalia

BG-Test and ADF-Test in Table 2 confirm a long-run relationship between y and x2. However, compared with other R-squared values, in Northern-Westphalia it is quite low and there is an unfavorable F-statistic.

Rhineland-Palatinate:

As assumed there exists a long-run relationship between y, x1 and x2 (table 2), however a long-run relationship with neutral technical change does not exist (table 5).

Schleswig-Holstein

Variables x1 and x3 are not C (2, 2) (see table 2) but C (2, 1) (not shown) and according to table 3, variables y, x2 and z=f(x1, x2) with appropriate integration vector is C (1, 1) (table 3). Therefore, we do not have spurious regression and results in table 4 and 5 are reliable.

Berlin

Y cannot be the dependent variable but x2. Test of co integration of variables y and x1 to be C (1, 1) is confirmed (table 2). Testing co integration of x2= a + 1*y + a1*x1 with co integration vector (1, a1) confirms a long-run relationship; however, multiple R-squared is very low compared to other estimates. Inhomogeneous and homogenous regression yield qualitative identical results (tables 4 respectively 5): number of engineers goes up as gross value added rises or as number of wage and salary earners shrinks.

Brandenburg

First, it has to be tested whether variables x1 and x3 are co integrated. According to table 2 column 'Brandenburg' there is C (2, 2). Therefore a long-run relationship between them holds and as capital stock rises, number of employment shrinks. Furthermore, co integration between y and x1, x3 might exist but x2 does not matter. Table 3 verifies this and homogenous regression of y on x1 and x3 is presented in table 5. The production elasiticities sum up to 1.04.

Saxony

According to table 2 variables x2 and x3 are C (1, 1) and variables y, x2 and x3 are C (0, 0) (see table 3) and insofar a long-run relationship holds. However, multiple R-squared is 0.07 and compared to other estimates quite low; even in table 4 it is with 0.33 very low and the sign of variable x2 is not plausible.

Saxony-Anhalt

Table 1 reveals that y cannot be the dependent variable; capital stock is the only possible one. Variables y and x2 are C (1, 1) (see table 2) and x3, y and x2 are C (0, 0) at significant level 0.1. Co integration analysis gives thus hints concerning causal relationships. As gross value added or number of engineer goes up, capital stock increases.

Thuringia

According to table 2, x2 and x3 are not C (2, 0); testing for C (2, 1) (not presented) confirms that they are C (2, 1) at significant level 0.1. Thus, a long-run relationship might hold between all variables and this is confirmed by table 3. Table 5 shows that x2 has implausible sign; production elasiticities sum up to 0.92, the same value we get with regression of y on x1 and x3 (not shown).

Dependent Variable	y	y	y	y	y	y
	Baden-Württem-berg	Bavaria	Hesse	Lower-Saxony	Northern-Westphalia	Rhineland-Palatine
Absolute Value	-70.563519	-3,904e+01*	Not possible	-6,93E+004	11,8330309 ***	see table 2
y	-	-	-	-	-	
x1	0,6	0,402		-1,65E+003		
x2	0.005224 **	0,001		-6,95E-001	-0.0007309	
x3	6,22	3,817e+00**		7,74E+003	-	
Multiple R-Squared:	0,78	0.9186		0.4405	0,26	
F-statistic:	8.252 on 3 and 7 DF, p-value: 0.01065	26.34 on 3 and 7 DF, p-value: 0.0003464		1.837 on 3 and 7 DF, p-value: 0.2284	3.085 on 1 and 9 DF, p-value: 0.1129	
BG-Test	0.8164, df = 1, p-value = 0.3662	0.1557, df = 1, p-value = 0.6931		0.4131, df = 1, p-value = 0.5204	0.0563, df = 1, p-value = 0.8124	
ADF-Test without drift	-2.1786 P VALUE: 0.03157	-2.8971 P VALUE: 0.01		-2.1788 P VALUE: 0.03155	-2.6404 P VALUE: 0.01074	

Table 4: Production Function with Absolute Value

Legend:

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

y: real Gross Value Added, logarithmic value

x1: number of occupied people without engineers, logarithmic value

x2: number of engineers

x3: capital stock, logarithmic value

Dependent Variable	y	x2	y	y	x3	y
	Schleswig-Holstein	Berlin	Branden-burg	Saxony	Saxony-Anhalt	Thuringia
Absolute Value	27,664723**	-426.35	12,16	4,890421 .	8,417686.	4,69
y	-	63,68		-	0,22	-
x1	1,514613**	-25.23	0,22066*	-	0,01118*	-0.2393021
x2	0,004921**	-	-	-0.002707	0,01118*	-0.0004594
x3	-2.528316*	-	-0.39052	0,462767 .	-	0,58
Multiple R-Squared:	0,87	0,06	0,83	0,33	0,6	0,96
F-statistic:	1.545 on 1 and 9 DF, p-value: 0.2452	0.2713 on 2 and 8 DF, p-value: 0.7691	19.67 on 2 and 8 DF, p-value: 0.000816	1.997 on 2 and 8 DF, p-value: 0.198	5.97 on 2 and 8 DF, p-value: 0.02591	57.28 on 3 and 7 DF, p-value: 2.72e-05
BG-Test	LM test = 0.0123, df = 1, p-value = 0.9115	LM test = 0.805, df = 1, p-value = 0.3696	LM test = 0.0075, df = 1, p-value = 0.931	LM test = 4.1972, df = 1, p-value = 0.04049	LM test = 0.509, df = 1, p-value = 0.4756	LM test = 0.0376, df = 1, p-value = 0.8462
ADF-Test without drift	: -2.5358 P VALUE: 0.01466	: -3.2032 P VALUE: 0.01	: -5.5106 P VALUE: 0.01	: -2.7776 P VALUE: 0.01	: -3.5637 P VALUE: 0.01	: -3.8864 P VALUE: 0.01

Table 4 (continued): Production Function with Absolute Value
Legend:
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
y: real Gross Value Added, logarithmic value
x1: number of occupied people without engineers, logarithmic value
x2: number of engineers
x3: capital stock, logarithmic value

Dependent Variable	y	y	y	y	y	y
	Baden-Württem-berg	Bavaria	Hesse	Lower-Saxony	Northern-Westphalia	Rhineland-Palatine
Absolute Value		-	-	-	-	-
y	-	-	-		-	-
x1	0,3	-0,45	1,62***	-0.024346	-	1,59***
x2	0.004656**	0,002	-	0,003442	0,07	0,011***
x3	0,69	1,169 ***	-	0,91	-	-
F-statistic:	3.22e+05 on 3 and 8 DF, p-value: < 2.2e-16	3.997e+05 on 3 and 8 DF, p-value: < 2.2e-16	4.947e+04 on 1 and 10 DF, p-value: < 2.2e-16	2.444e+05 on 3 and 8 DF, p-value: < 2.2e-16	2035 on 1 and 10 DF, p-value: 6.898e-13	1.434e+05 on 2 and 9 DF, p-value: < 2.2e-16
BG-Test	0.12, df = 1, p-value = 0.729	2.3184, df = 1, p-value = 0.1278	7.6163, df = 3, p-value = 0.05465	0.9566, df = 1, p-value = 0.3280	2.178, df = 1, p-value = 0.14	0.881, df = 1, p-value = 0.3479
ADF-Test without drift	-1.6469 P VALUE: 0.0933	-2.5839 P VALUE: 0.01285	-0.0121 P VALUE: 0.6041	-2.4296 P VALUE: 0.01864	-1.4467 P VALUE: 0.1487	-1.147 P VALUE: 0.2438

Table 5: Production Function without Absolute Value
Legend:
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
y: real Gross Value Added, logarithmic value
x1: number of occupied people without engineers, logarithmic value
x2: number of engineers
x3: capital stock, logarithmic value

Dependent Variable	y	x2	y	y	x3	y
	Schleswig-Holstein	Berlin	Brandenburg	Saxony	Saxony-Anhalt	Thuringia
Absolute Value	-	-	-	-	-	-
y	-	6,28	-	-	1,109728***	-
x1	-0.1364014	-2,93	0,34	-	-	0,05
x2	0,000107	-	-	-0.005791 **	0,015827**	-0.000274
x3	0,97	-	0,7	0,915116***	-	0,87
F-statistic:	5.327e+05 on 3 and 8 DF, p-value: < 2.2e-16	621.8 on 2 and 9 DF, p-value: 2.26e-10	4.898e+05 on 2 and 9 DF, p-value: < 2.2e-16	4.218e+05 on 2 and 9 DF, p-value: < 2.2e-16	2.866e+05 on 2 and 9 DF, p-value: < 2.2e-16	1.013e+06 on 3 and 8 DF, p-value: < 2.2e-16
BG-Test	0.2566, df = 1, p-value = 0.6125	0.7109, df = 1, p-value = 0.3992	0.3375, df = 1, p-value = 0.5613	1.5616, df = 1, p-value = 0.2114	0.015, df = 1, p-value = 0.9026	0.017, df = 1, p-value = 0.8962
ADF-Test without drift	-2.612 P VALUE: 0.0118	-3.347 P VALUE: 0.01	-4.618 P VALUE: 0.01	-2.4257 P VALUE: 0.01879	-3.3594 P VALUE: 0.01	-3.4677 P VALUE: 0.01

Table 5 (continued): Production Function without Absolute Value

Legend:

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

y: real Gross Value Added, logarithmic value

x1: number of occupied people without engineers, logarithmic value

x2: number of engineers

x3: capital stock, logarithmic value

Result

Assuming neutral technical change, number of engineers has in West-Germany a positive influence (besides Hesse) but in Eastern-Germany inclusive Berlin there is either no influence at all or the estimated parameters have wrong sign. In Saxony-Anhalt capital stock and in Berlin number of engineers are dependent variables respectively and not gross value added. Hence, our hypothesis that engineers are differently employed in Western and Eastern Germany cannot be rejected and this goes along with patent efficiency patterns.

Here, Cobb-Douglas production functions with neutral technical change are estimated without imposing any restrictions on the sum of production elasticities. Interestingly, the sum equals sometimes almost exactly 1 which being often superimposed in estimations of potential production functions (SVR, 2003) to get estimations of neutral technical change. Hence, interpretation of engineers as source of patents and innovations seems to be a useful way to get additional insight in innovation processes and economic growth.

Our hypothesis cannot be rejected but our explanation is based on a lot of assumptions and speculations not tested at all. Therefore, some empirical work remains to be done. Far reaching economic policy consequences are difficult to draw because we had to know something about relevant alternatives. Nevertheless, a) long-run relationships seem to be an important factor in innovation processes and b) transferring successful structures into other regions appears to be difficult but we are able to show critical factors.

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