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Rapid demographic change and the allocation of public education resources: evidence from East Germany

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Abstract:

We analyse the adjustment of public education spending in response to rapidly decreasing student cohorts in East Germany where birth rates collapsed after German reunification. Previous results from the literature based on data from more stable demographic periods suggest that public resources are incompletely adjusted, and that large reductions in the student population would thus translate into major increases in spending per student. Our empirical analysis suggests, however, that resource adjustments in East Germany have been considerable, especially in the years when student cohorts actually decreased. Adjustments were less tight when student numbers began to stagnate. Although our results are restricted to public education, they may be interpreted as early evidence on fiscal adjustments during strong demographic change, which will play a growing role in the years to come.

Keywords: Subnational government spending, demographic change, public education

JEL-Classification: I22, J18, H72

Non technical summary

Germany and other industrialised nations will face severe demographic shifts in the coming decades. It is an open question how fast the economies and the public sectors can adjust to these demographic changes. For example, changing student cohort size is a major aspect for the public sector. Previous empirical evidence about the link between public education spending and student cohort size suggests that spending is not adjusted proportionately to varying sizes of the student cohort and that a large decrease in the number of students would thus translate into an important increase in education spending per student rather than into a significant decrease in resources allocated to public education (see Poterba, 1997 for the U.S. or Baum and Seitz, 2003 for West Germany). However, these studies examine data sets with rather modest demographic changes which do not reflect the magnitude and the rapidity of the upcoming demographic developments.

East Germany after reunification provides the setting for a unique experiment of rapidly decreasing student cohort size. As a consequence of an all-time low in the fertility rate of 0.77 children per woman in the East German Länder during the early 1990s, student enrolment in primary schools decreased sharply, and by 2002 the number of pupils was below 50% of the 1993 level. In this study, *first*, we measure the elasticity of education spending per student in response to strong shifts in cohort size and compare it to the adjustment to weaker changes. There are plausible reasons to expect stronger adjustment in times of larger demographic shifts (for example, it may be rational not to adjust during small, rather cyclical demographic changes), but weaker or slower adjustments are also conceivable (due to a lacking of flexibility in the public sector, for instance). *Second*, we analyse the composition of the adjustment response (in terms of combinations of class size, teaching hours per teacher and teaching time per class) during strong/weak demographic shifts. *Finally*, we make some tentative judgement of the quality of the adjustment package.

Panel data on physical education resources (number of teachers, classes, teaching hours) in the five East German Länder over the 1993-2006 period suggests that resource adjustments have been considerable in the years when student cohorts actually decreased (1993-2002). This finding challenges the view that the East German Länder experienced major problems in adjusting teaching capacity due to employment protection (at least with the East German model of teacher employment). After 2001 adjustments have been less stringent, such that over the 1993-2006 period, the 50%-decrease in cohort size has still translated into a 25% increase in the teacher/student-ratio. Due to the small data set and limitations of the econometric model, we cannot claim that the estimated elasticities are net of common shifts in the demand for public education (for example, following the publication of the PISA test in autumn 2001), which suggests a cautious interpretation.

The adjustment package mainly consists of smaller class size (but less than what we would expect from the West German adjustment response) and less teaching time per teacher, which probably also reflects the fact that more substitute teachers were available helping to avoid the cancellation of teaching time during teacher absences. A quick review of the literature on educational production suggests that this adjustment package probably contains an important share of investment into human capital formation (which can be expected to translate into better student performance in the future) but also some fraction of demographic costs (which cannot be expected to increase future student performance).

Nicht technische Zusammenfassung

In den kommenden Jahren stehen Deutschland und andere Industrienationen vor erheblichen demographischen Veränderungen. Eine Frage ist, wie schnell sich die Volkswirtschaften und die öffentlichen Sektoren an die veränderten demographischen Bedingungen anpassen. Für den öffentlichen Sektor sind dabei Änderungen der Schülerzahlen von erheblicher Bedeutung. Die vorhandene empirische Evidenz zur Anpassung öffentlicher Bildungsausgaben an Veränderungen in der Größe der Schülerkohorte legt nahe, dass die Ausgaben nur unvollständig an Veränderungen der Schülerzahl angepasst werden (für die USA siehe z.B. Poterba, 1997; für Westdeutschland siehe Baum und Seitz, 2003). Dieses Ergebnis impliziert für den Fall starker Rückgänge der Schülerzahl, dass die Bildungsausgaben pro Schüler deutlich ansteigen und die Ressourcenausstattungen im Bildungswesen insgesamt unterproportional reduziert würden. Allerdings beruhen diese Studien auf Datensätzen, die eher langsame demographische Veränderungen widerspiegeln.

Ostdeutschland nach der Wiedervereinigung bietet hierzu ein einzigartiges Experiment. In der Folge eines drastischen Einbruchs der Geburtenzahlen bis auf 0,77 Geburten pro Frau in den ostdeutschen Ländern in den frühen 1990er Jahren, gingen die Schülerzahlen in den Grundschulen von 1993 bis 2002 – nachhaltig – um etwa 50 % zurück. In dieser Studie werden drei Aspekte untersucht: *Erstens* messen wir die Elastizität der öffentlich bereitgestellten Bildungsressourcen in Reaktion auf den starken Schülerrückgang und vergleichen diese mit Anpassungsreaktionen aus vergleichsweise stabilen demographischen Zeiten. Dabei kann für Zeiten starker demographischer Veränderungen sowohl eine stärkere (schnellere) Anpassung vermutet werden (z.B. weil bei geringfügigen, zyklischen demographischen Schwankungen der weitgehende Verzicht auf Anpassungen rational ist); aber auch eine schwächere Anpassung erscheint plausibel (z.B. aufgrund stärkerer politischer Widerstände von Lehrergewerkschaften oder einer geringen Flexibilität im öffentlichen Sektor hinsichtlich der Anpassungsinstrumente). Die Verwendung von physischen Ressourcenvariablen (Klassengröße, Unterrichtszeit pro Klasse, Unterrichtszeit pro Lehrer) erlaubt es *zweitens*, die Zusammensetzung der Anpassungsreaktion zu untersuchen, deren Qualität wir *drittens* basierend auf einer kurzen Literaturübersicht aus der empirischen Bildungsökonomik rudimentär bewerten.

Die empirischen Befunde für die fünf ostdeutschen Bundesländer legen nahe, dass die Anpassungsreaktion im Zeitraum bis 2002 (in dem die Schülerzahlen tatsächlich sanken) signifikant stärker war als bisher in der Literatur gemessen. Dieses Resultat deutet an, dass der öffentliche Sektor in den ostdeutschen Ländern durchaus in der Lage war, auf den starken Schülerrückgang zu reagieren. Allerdings ist das Ergebnis nicht ohne weiteres auf die westdeutschen Länder übertragbar, insbesondere aufgrund des höheren Anteils verbeamteter Lehrer in den Westländern. Nach 2001 ging die Anpassungsintensität deutlich zurück, und über den gesamten Beobachtungszeitraum von 1993 bis 2006 stieg der Lehrer/Schüler-Quotient in Reaktion auf den 50prozentigen Schülerrückgang um etwa 25 %. Dabei kann jedoch – aufgrund des kleinen Datensatzes und damit einher gehender begrenzter Aussagekraft des ökonometrischen Modells – nicht ausgeschlossen werden, dass Präferenzen für steigende Bildungsausgaben im Gefolge des ersten „PISA-Schocks“ im Jahr 2001 hier eine Rolle spielen.

Die Anpassungsreaktion setzt sich in erster Linie zusammen aus kleineren Klassen und weniger Unterrichtszeit pro Lehrer; letzteres Instrument dürfte dabei auch die Vorhaltung von mehr Vertretungsreserven reflektieren. Insgesamt könnte der gestiegene Lehrer/Schüler-Quotient so zum Teil als Investition in Humankapital interpretiert werden, zum Teil allerdings auch als demographiebedingte Kostensteigerung.

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Rapid demographic change and the allocation of public education resources: evidence from East Germany[1]

1 Introduction

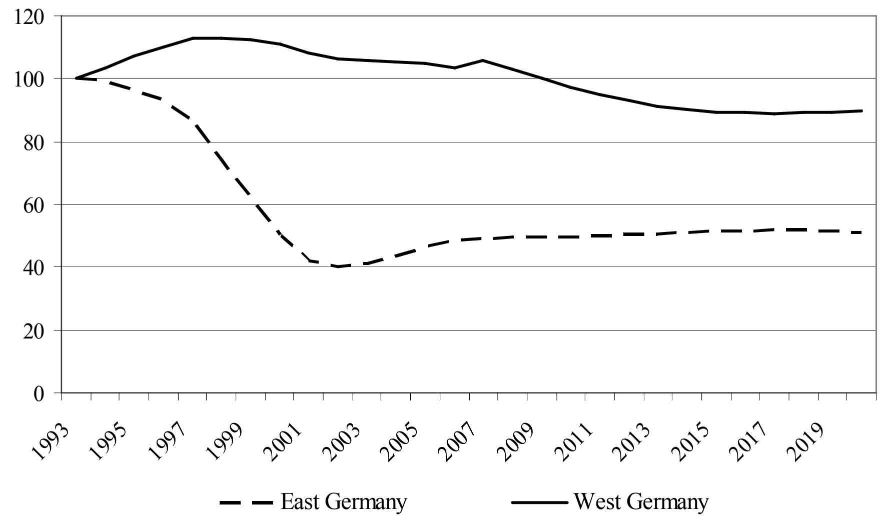
It is a well-known fact that many industrialised nations will face unprecedented demographic shifts in the course of the 21st century. A substantial literature deals with the economic and fiscal consequences of ageing, including with respect to public education systems (e.g. Gradstein and Kaganovich, 2004 for theoretical research, and Poterba, 1997 or Cattaneo and Wolter, 2009 for empirical papers). Empirical evidence for several countries on the link between education spending and the size of student cohorts suggests that (total) education spending is virtually independent of cohort size (see Poterba, 1997 for the U.S. or Baum and Seitz, 2003 for West Germany). However, a fundamental problem encountered in this work is that these studies examine data sets with rather modest demographic changes which do not reflect the magnitude and the rapidity of the upcoming demographic changes. The question arises as to whether these results also hold under conditions of rapid demographic change. Poterba (1997, 59) puts it more generally and urges: *"further analysis of the link between cohort size and per-pupil spending, perhaps using changes in enrollment that result from exogenous shocks…"*.

In this paper we identify resource adjustments exploiting strong and exogenous variation in student cohort size. We use a unique demographic shock in East Germany where – following reunification – the fertility rate hit an all-time low of 0.77 children per woman and where a significant share of families with school-age children migrated to the western part of the nation. As a consequence, student enrolment in East German primary schools decreased sharply in the mid-1990s. By 2002 the number of pupils was

[1] This article is based on my dissertation which has benefited much from the supervision of Helmut Seitz. I wish to thank Torberg Falch, Viktor Steiner and Heinz Herrmann for their very helpful remarks. I would also like to thank seminar participants at the Conferences of the Public Choice Society and of the IIPF for their useful remarks and suggestions. All errors are my responsibility. Financial support from the German Research Foundation (DFG) is gratefully acknowledged (SE 540/2-2). The views expressed in this paper do not necessarily reflect the views of Deutsche Bundesbank or of its staff. Email: gerhard.kempkes@bundesbank.de. Tel.: +49 69 9566 3353.

below 50% of the 1993 level and will not exceed 50% until 2020. Enrolment in the West German Länder, by contrast, exhibits a significantly less pronounced downward trend and until 2020, enrolment will still be at about 90% of the 1993 level (see Figure 1).

Figure 1: Student enrolment in primary schools in East and West Germany (1993-2020). Normalised time series (1993=100)



Data source: Standing Conference of German Länder Education Ministers (various years).

The Länder, which assume the major responsibility for the German education system, share a common legal and institutional background. Furthermore, owing to the highly equalising fiscal equalisation system, all Länder have roughly similar fiscal endowments. This common framework facilitates comparisons vis-à-vis cross-country studies. Thus, Germany is well-suited to being used as a natural laboratory for studying the impact of strong and rapid demographic shifts on the provision of education resources (in the East German Länder), which can be compared directly with adjustment processes in times of smooth demographic changes (in the West German Länder). In particular, we study three issues. *First*, we measure the elasticity of education spending per student to strong shifts in cohort size and compare it with the adjustment in response to weaker changes. There are reasons to expect stronger adjustment in times of larger demographic shifts (for example, it may be rational not to adjust during small, rather cyclical demographic changes), but weaker or slower adjustments are also conceivable (due to a lacking of flexibility in the public sector, for instance). *Second*, we analyse the composition of the adjustment response (in terms of combinations of class size, teaching hours per teacher, and teaching time per class) during strong/weak demographic shifts. *Finally*, we make some tentative judgement of the quality of the adjustment packages based on a quick review of the literature on educational production. Thus, our paper may also be read as an early piece of evidence on quantitative and qualitative aspects of fiscal adjustments in times of strong demographic shifts.

Panel data on physical education resources (number of teachers, classes, teaching hours) in the five East German Länder over the 1993-2006 period suggests that resource adjustments were considerable, especially in the years when student cohorts actually decreased (1993-2002). In this period, resource adjustment was significantly different from public policy in demographically more stable periods. After 2000-2001, adjustments were less stringent, such that over the 1993-2006 period, the 50% decrease in cohort size translated into a 25% increase in the teacher/student-ratio, which is not significantly different from the elasticity obtained from West German data for the same period. However, owing to the small sample and corresponding limitations of the econometric model, we cannot claim that the estimated elasticities are net of common shifts in the demand for public education following the publication of the PISA test in autumn 2001. The adjustment package consists mainly of smaller class sizes (but less than what we would expect from the West German adjustment response) and less teaching time per teacher, which probably also reflects the fact that more substitute teachers were available, which helped to avoid the cancellation of teaching time during teacher absences. These measures probably bear a major share of productive spending – which can be expected to translate into better student performance – besides demographic costs.

The paper is organised as follows: Section 2 reviews evidence on the link between cohort size and public education spending, discusses our decomposition of education spending into physical resource inputs, and reports basic information about the German educational institutions. Section 3 introduces the data. Section 4 presents the empirical strategy and discusses the results. Section 5 concludes.

2 Relevant background

2.1 Existing empirical evidence

A substantial body of empirical work has investigated the determinants of education spending (Denzau, 1975; Ladd, 1975; Lovell, 1978 or Rubinfeld and Shapiro, 1989). Although these studies are related to this paper, we focus on studies examining the impact of varying sizes of student cohorts on education expenditures. Schultz (1988) presents international evidence based on a wide panel of 89 countries from 1960 to 1980. His results suggest that education spending per student in primary education is reduced by 1.1% in response to a 1% increase in the size of the student cohort, i.e. total education spending is not adjusted in response to varying sizes of student cohorts.[2]

For the U.S. states from 1960 to 1990, Poterba (1997, 1998) also estimates an elasticity of -1 of education spending per student with respect to varying sizes of the student cohort. This result is confirmed for the state level by several studies (Fernandez and Rogerson, 2001; Harris, Evans and Schwab, 2001; Ladd and Murray, 2001). Studies based on county and school district data find elasticities that tend to be smaller than those obtained from state-level data. Ladd and Murray (2001) investigate county-level data and estimate an elasticity of about -0.4. Harris, Evans and Schwab (2001) present estimates that are within a range of -0.3 to -0.5 for the school district level.

Evidence for the Swiss Cantons is presented by Grob and Wolter (2007). They derive an elasticity of about -0.6 of school spending per pupil in Swiss primary schools to variations in enrolment. Borge and Rattsø (1995) confirm these findings for Norwegian local governments. Although declining age groups consume fewer total expenditures, local governments' adjustment is rather slow. This leads to increasing education expenditures per pupil as age cohorts decrease, which is broadly consistent with the results from U.S. counties and Swiss Cantons.

Baum and Seitz (2003) report results from a panel of West German Länder over the 1975-1999 period. Alternative specifications of the expenditure (endogenous) variable are tested. The Länder-level estimates range from -0.75 for staff expenditures to -0.83

[2] The polar cases of the elasticity of education spending per student to changes in cohort size are -1 if total education expenditures are not adjusted and 0 if total education expenditures are adjusted proportionately.

for the teacher/student-ratio. This suggests that adjustment to varying cohort size is sluggish and is largely in accordance with the evidence from the U.S. states.[3]

Note that the results based on expenditure data and on physical education resources (here: teacher/student-ratio) yield similar results, which is highly plausible since about 90% of education spending at the Länder level accrue to teacher salaries. An advantage of using data on teacher/student-ratios instead of expenditure data is that it can be further decomposed into class size, teaching time per class, etc., which is practised in this paper and described in Section 2.2.

In short, existing empirical evidence suggests that there is a strong negative relationship between student cohort size and education spending per student, which implies sluggish adjustment of total education spending to varying student numbers. This finding applies more to higher levels of government (state/Länder) than to the local government level. However, all empirical evidence presented in the literature is derived from countries with rather modest changes in the age composition of the population.[4]

2.2 A decomposition of education spending

During episodes of decreasing student cohort size, incomplete adjustment of total education resources implies that resources per student increase. From the view of educational effectiveness, there is the question about the allocation of increased spending per student in terms of physical education resources: what does increased spending per student buy? Higher per student expenditures can be directed to smaller classes, more teaching time per class or less teaching time per teacher. Thus, additional education expenditures per student can be due to various sources and do not necessarily benefit students' learning environment.

Decomposing education expenditures allows us to assess the changes in students' learning environment that may occur during the (non)-adjustment of resources. With

[3] The estimates for the local level in West Germany show somewhat greater variation and are often not significantly different from zero. However, the elasticity for current expenditures (without staff expenditures) is in line with the U.S. results (-0.4). Recall that, at the local level, the bulk of expenditures accrue to non-wage spending.

[4] One exception is the paper by Schultz (1988). However, in his broad cross-section of countries, which includes developing countries, growing student cohorts prevail.

respect to teaching capacity, which is measured as full-time equivalent (fte) teachers[5] below, Länder governments – explicitly or implicitly – respond by

- reducing the number of fte teachers, or reducing teaching time per fte teacher with a corresponding reduction in teacher wage: "compulsory part-time"
- reducing teaching time per fte teacher *without* reducing fte teacher wage
- reducing class size
- increasing teaching time per class or reducing loss of instructional time by increasing the availability of substitute teachers.

These measures can be combined to form different "adjustment bundles". An adequate decomposition of spending per student (E/ST) is obtained by modifying Falch and Rattsø's approach (1997) [6]

(1) $$\left(\frac{E}{St}\right)=\left(\frac{W}{T}+\frac{NW}{T}\right)\cdot\left(\frac{T}{Tt}\right)\cdot\left(\frac{Tt}{Cl}\right)\cdot\left(\frac{Cl}{St}\right)$$

where E denotes total education spending, St is the number of students, W denotes the total wage bill of primary school teachers, while NW denotes total non-wage spending for primary schools, T is the number of fte teachers. Tt and Cl denote total instructional time and the number of classes, respectively. Thus, W/T denotes wage spending per full-time equivalent (fte) teacher, while NW/T represents non-wage spending per fte teacher. T/Tt is the number of fte teachers divided by total teaching hours and expresses the fraction of an fte teacher needed for the provision of one teaching hour. Tt/Cl is the teaching time per class and Cl/St denotes inverted class size and expresses the fragment of a class that is provided for one student. Non-wage spending per fte teacher (NW/T) is approximated by the number of school locations per fte teacher. Although this approximation is enforced by the lack of comparable expenditure data, it is not unrealistic in the context of primary education: apart from school buildings, little additional equipment is used in the education of 6-10 year old pupils compared with the laboratory- and computer-intensive equipment of older students. Appendix 1 provides a

[5] The concept of full-time equivalents takes into account the fact that some teachers work only part-time. Thus, the number of full-time equivalent teachers is a calculative number and may differ from the number of (physical) teachers employed in a Land.

[6] For primary education in Germany, the enrolment ratio is of no relevance since it is practically 100%. Since there are virtually no private primary schools in East Germany, the division of pupils between private and public schools can also be disregarded.

brief overview of the literature on the effectiveness of the spending elements on the right-hand side of Equation (1).

2.3 Germany's educational institutions in a nutshell

Education is a major responsibility of the Länder governments as enshrined in the German Constitution. In primary and secondary education, Länder governments share responsibility with the local level. About 80% of primary and secondary education expenditures are borne by the Länder and 20% by the municipalities (Gemeinden).[7] Länder are in charge of teaching staff, while the local governments provide school infrastructure and pay for non-teaching staff. This represents a significant component of total public expenditure, at both the Länder and the local level. On average, primary and secondary education spending make up 36% of the total wage bill at the Länder level (excluding city states) and 14% of total capital spending at the local level.[8] Länder responsibility is reflected in different employment models for teachers across the Länder. Whereas the majority of teachers in East Germany are employed as regular public sector employees, the vast majority of teachers in West Germany are public servants who enjoy special employment protection.

Länder responsibility also results in marked differences in education institutions across the 16 Länder. Nevertheless, primary education is organised quite homogeneously: students typically enter primary schools at the age of six and leave primary schools after the fourth grade (at the age of ten).[9]

Finally, the policy of resource adjustments in the East German Länder is worth mentioning. Länder governments and teachers' unions have mutually agreed on reductions in working hours for teachers in primary schools accompanied by a proportional reduction in teachers' wages (about 60% to 80% of a regular full-time teacher). In turn, Länder governments have often refrained from firing teachers. There is

[7] Although local governments are involved in providing primary and secondary education, the Länder assume the general power of decision.

[8] However, local governments receive a considerable amount of grants from the Länder to finance school expenditures. Expenditure data refers to 2004.

[9] Students stay in primary schools for six years in Berlin and Brandenburg. Currently, Hamburg is implementing six-year primary education as of summer 2010.

a time limit on these agreements, which typically end in 2010. Reductions in working hours have been flanked by agreements on early retirement and offers of compensation.

3 Data and summary statistics

We concentrate on primary education (grades one to four) because primary education is comparable across the Länder and because it fully reflects the demographic shock. However, comparable expenditure data or appropriate test score data for primary education are not available owing to accounting differences across the Länder. The Standing Conference of German Länder Education Ministers publishes data on physical resource indicators, which are comparable across Länder, i.e. the number of teachers (T), students (St), classes (Cl) and teaching time (Tt).[10] All other data are from various publications by the Federal Statistical Office of Germany. The final panel data set covers yearly data (1993-2006) for the five East German Länder: Brandenburg (BB), Mecklenburg-Vorpomerania (MV), Saxony (SN), Saxony-Anhalt (ST) and Thuringia (TH). Earlier years are not included owing to the transformation process in the East German educational system (Weiß and Weishaupt, 1999, 114). The East German panel thus contains 70 (5x14) observations. An identical data set is created for the eight West German non-city Länder: Baden-Württemberg (BW), Bavaria (BY), Hesse (HE), Lower Saxony (NI), North-Rhine Westphalia (NW), Rhineland-Palatinate (RP), Saarland (SL) and Schleswig-Holstein (SH). The city states of Berlin, Bremen and Hamburg have different institutions regarding the tasks of the Länder and are therefore excluded. Recall that the sole purpose of the analysis of West Germany is a comparison with the findings from East Germany.

The measurement of the number of teachers (T) and teaching time (Tt) is worth a more detailed presentation (see Standing Conference of German Länder Education Ministers, 2006). As mentioned above, the number of teachers (T) is measured as full-time equivalents. Spare teachers, i.e. substitute or supply teachers who are used to prevent instructional time from being cancelled owing to illness etc., are also billed, irrespective

[10] This data accounts for Brandenburg primary schools such that only grades one to four are included (see Standing Conference of German Länder Education Ministers, 2002, 34).

of whether this "on-call capacity" was actually used or not.[11] The teacher/student-ratio (T/St) is therefore considered to be an excellent resource indicator, but is less well-suited to describing the learning environment of students (Standing Conference of German Länder Education Ministers, 2002, 96). Teaching time (Tt) is measured as total teaching hours in a Land. Teaching that is performed by substitute teachers owing to illness, etc., is not counted twice. Hence, teaching time per teacher, Tt/T, is not easily comparable across Länder because spare teaching capacity is not billed and fewer teaching hours per teacher may reflect a higher spare teaching capacity on call, which suggests cautious interpretations of Tt/T.[12]

Table 1: Summary statistics (5 East and 8 West German Länder, 1993-2006)

Variable	Variable description	Sample	Mean	S. d.	Min / Max
T/St	Fte teacher per student	East	0.057	0.010	0.043 / 0.082
		West	0.048	0.003	0.043 / 0.055
NW/T	Number of school locations per fte teacher	East	0.124	0.020	0.088 / 0.163
		West	0.109	0.013	0.078 / 0.154
Tt/T	Teaching hours per fte teacher	East	23.806	1.728	18.525 / 27.956
		West	25.326	1.132	23.425 / 30.961
St/Cl	Students per class	East	19.954	1.553	16.968 / 22.641
		West	22.108	1.120	19.639 / 24.550
Tt/Cl	Teaching hours per class	East	26.540	1.767	22.994 / 31.108
		West	26.676	1.540	24.260 / 29.822
St	Number of students	East	100 446	47 050	39 888 / 231 189
		West	337 773	229 701	37 350 / 828 374
PR	Real Länder public revenue per capita	East	3 385	242	2 802 / 3 824
		West	2 522	233	2 160 / 3 241
PD	Population density: inhabitants per km^2	East	137	59	73 / 250
		West	280	124	161 / 531
UR	Unemployment rate	East	0.186	0.021	0.142 / 0.221
		West	0.095	0.019	0.055 / 0.136
FS	Share of foreign students	East	0.015	0.009	0.002 / 0.034
		West	0.110	0.036	0.052 / 0.173
ES	Share of population older than 60 years	East	0.237	0.031	0.170 / 0.290
		West	0.232	0.017	0.194 / 0.266

Note: Public revenue per capita is reported in 2000 euros, with deflation across years using the deflator for government consumption taken from the 2007 Report of the German Council of Economic Experts. Fte denotes full time equivalent teacher.

[11] Note that, in Germany, the term substitute teacher (Vertretungsreserve) denotes teachers who are on call for the event of another teacher not being able to give classroom instruction on account of illness, accidents, etc. Generally, these teachers are employed as regular teachers within the same school and serve some part of their working time on call.

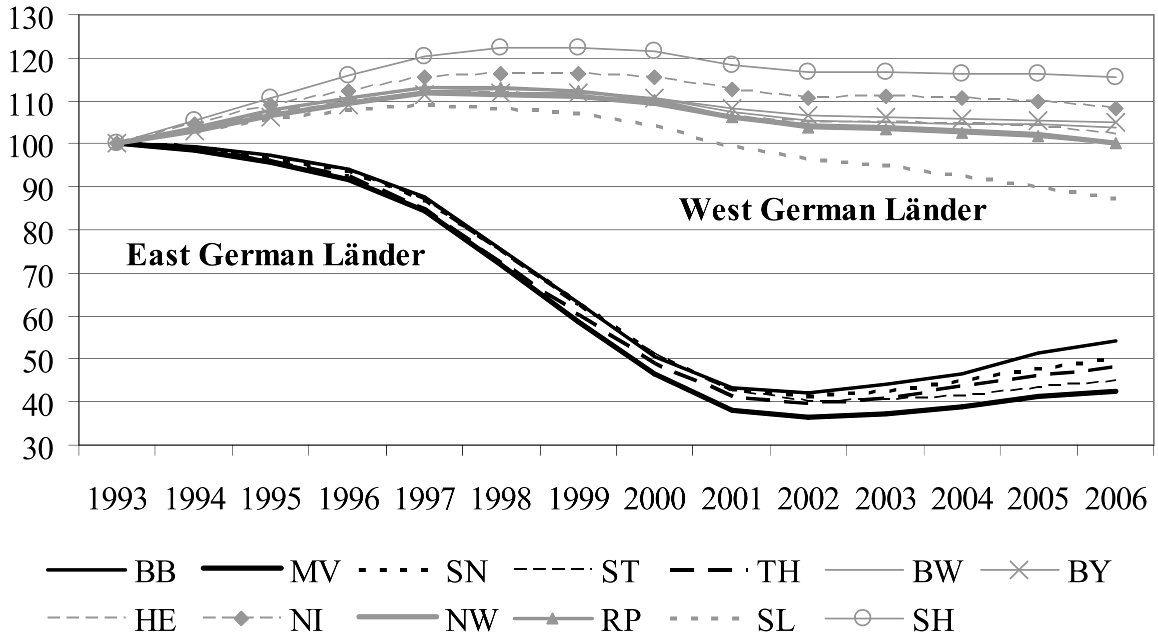
[12] Since the coefficients in this study are identified from within-Länder variation, limited cross-Länder comparability may be of somewhat limited concern.

Table 1 reports summary statistics with respect to the key variables (students and teaching resources), but also with respect to the control variables (public revenue, etc.). Generally, the teacher/student-ratio in East Germany is on average about 16% higher than in West Germany. The minima for this ratio are identical while the standard deviation for the West German Länder is only one-third of the East German standard deviation. Examining the spending components, Table 1 shows that East German teachers teach about 6% less on average than their West German counterparts. In addition, the standard deviation is much higher than in the western part of the nation. While the teaching load maximum is about 10% lower in East Germany, minimum teaching hours per teacher in East Germany are more than 20% below the West German minimum. To some extent, this may indicate that more spare capacity was available on call in the East German Länder. Average class size is about 10% smaller in the East German Länder. While teaching hours per class are on average roughly equal across East and West German Länder, the maxima and minima suggest a higher variation in the East German Länder. Table 1 shows considerable variation of student numbers in both East and West Germany. However, much of the variation in student numbers – and also in education resources – comes from cross-Länder variation, while the focus of the present study is on variation within Länder.

Figure 2 presents the within variation of student cohort size for the East German Länder (black lines) and for the West German Länder (grey lines). It is evident that the within variation in East Germany is much stronger than in the Western Länder. The size of the relevant student cohorts in the East German Länder decreases by up to 65% from 1993 to 2002, whereas the number of students in the West German Länder increases by up to 20% from 1993 until 1998.

Moreover, Figure 2 shows that the evolutions of student numbers are almost identical across the East German Länder from 1993 to 2000 (see the slopes). The correlation coefficient of the time-series variation across the five East German Länder over the 1993-2006 period is 99.8%. The within variation across the West German Länder is less highly correlated (81.8%). The reason for the highly similar demographic variation in East Germany may be that German reunification induced a sharp decrease in birth rates across all East German Länder in a similar fashion.

Figure 2: The number of students in primary schools across the East German Länder and across the West German Länder (1993-2006). Normalised time series (1993=100)



Data source: Standing Conference of German Länder Education Ministers (various years).

The highly correlated within variation in student cohort size is problematic for the econometric models, which will be described in the following section. Typically, the models that are used to evaluate the link between cohort size and spending per student exploit panel data, which enables them to account for economy-wide shocks by including year fixed effects (FE) in the specification. Separation of the effects from common shocks and from changes in the size of Länder-specific student cohorts is impossible if the within-Länder variation of cohort size is perfectly correlated across the Länder. In this case, there is strong multi-collinearity between the change in student numbers and the year fixed effects, which has the typical consequences for the estimation (high standard errors, unstable estimation results; see for example, Kennedy, 2003, 213).

Finally, with respect to the control variables, Table 1 shows that the economic and geographic background differs considerably in East and West Germany. Foreign students represent an important share of the student cohort in the Western part of the country (about 11% on average), whereas the share of non-German students is marginal in the East German Länder. The unemployment rate in the West is only about 50% of the East German unemployment rate, while population density in the East German

Länder is not even half as high as in the West German Länder. Despite the weaker economic situation in East Germany, public revenue per capita in the sample period is, on average, more than 30% higher than in the West German Länder, owing to the strong fiscal equalisation system in Germany and federal grants to the East German Länder.[13]

4 Empirical analysis

The goal of the empirical analysis is to investigate the effect of the sharp fall in the number of pupils on resource allocation in primary education based on panel data for the five East German Länder over the 1993-2006 period. The results are compared to similar regressions results estimated with West German data for the same period. Section 4.1 briefly presents descriptive evidence on how spending components evolved over time in East and West Germany. The empirical strategy and the corresponding econometric models are described in Section 4.2. The results are presented in Section 4.3.

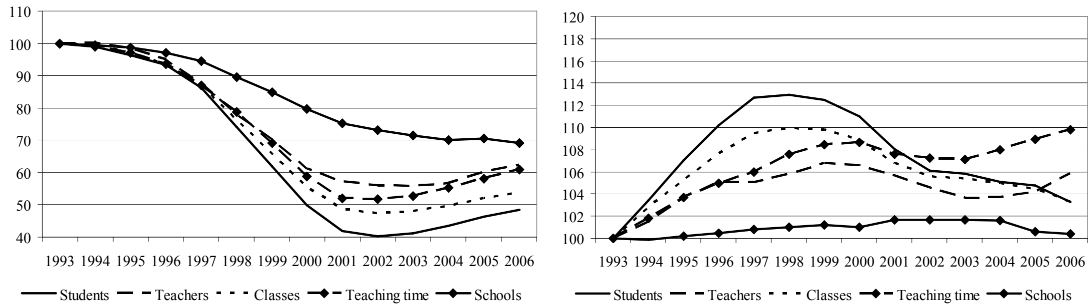
4.1 Descriptive evidence

Figures 3 and 4 give descriptive overviews of the time-series variation in spending components for East Germany (panel a) and West Germany (panel b). Figure 3 directly reports the number of fte teachers (T), classes (Cl), teaching hours (Tt) and students (St), and Figure 4 maps the spending components as given in Equation (1).

[13] Federal grants to East Germany follow a declining path and will cease in 2019; details in Seitz et al. (2007b).

Figure 3: The number of students and physical schooling inputs (1993-2006).
Normalised time series (1993=100)

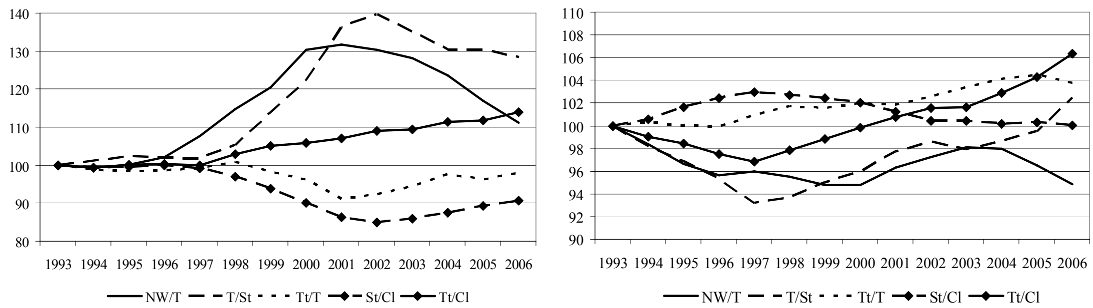
(a) East Germany (b) West Germany



Data source: Standing Conference of German Länder Education Ministers (various years).

Figure 4: Key components of education spending (1993-2006).
Normalised time series (1993=100)

(a) East Germany (b) West Germany



Data source: Standing Conference of German Länder Education Ministers (various years).

4.2 Empirical strategy and the econometric model

The starting point for a more formal empirical analysis is the decomposition of education spending. Rearranging and taking natural logarithms of Equation (1) yields

$$\text{(2)} \qquad \ln\left(\frac{E}{St}\right) = \ln\left(\frac{W}{T} + \frac{NW}{T}\right) - \ln\left(\frac{Tt}{T}\right) - \ln\left(\frac{St}{Cl}\right) + \ln\left(\frac{Tt}{Cl}\right)$$

Note that the adjustment of education expenditures to shifts in the size of the student cohort may affect the physical resource variables on the right-hand side of Equation (2). Thus, potentially all spending components are functions of the number of students, and deriving (2) with respect to ln(St) yields the elasticity of education spending per student to variations in student numbers ($\alpha_{E/St,St}$), which may be written as

$$\text{(3)} \qquad \alpha_{E/St,St} = \alpha_{(W+NW)/T,St} - \alpha_{Tt/T,St} - \alpha_{St/Cl,St} + \alpha_{Tt/Cl,St}$$

However, not every adjustment package necessarily effects all spending components. If, for example, teaching capacity (T) and schooling infrastructure (NW) are adjusted proportionately to the shifts in the size of the student cohort, all elasticities on the right-hand side of Equation (3) will be zero as well as the overall elasticity ($\alpha_{E/St,St}$). If education spending is *not* adjusted to increasing/decreasing student cohorts, only class size (St/Cl) increases/decreases and the other spending components remain unchanged, i.e. only $\alpha_{St/Cl,St}$ takes a value different from 0, namely -1.

Whereas data for estimation of the last three elasticities on the right-hand side of Equation (3) are available, comparable information on expenditures for primary education is non-existent. Therefore, some further empirical considerations on $\alpha_{(NW+W)/T,St}$ are necessary. *First*, an effect of primary education student numbers on public sector wages (W/T) is implausible from an institutional point of view in Germany. Primary school teachers earn general public sector wages, but represent only a small fraction of public sector employees. In the sample period, public sector wages were determined at the federal level in negotiations between the federal/Länder governments and public sector unions. Consequently, there is no foundation for the hypothesis that the number of students in East German primary schools has an effect on general public sector wages (W/T). The elasticity of student numbers on teacher wages can thus be neglected in the analysis. *Second*, the Länder are not responsible for non-wage spending (NW). On average, about 12% of education budgets at the Länder level is allocated to purposes other than wage-spending. Thus, if one wants to compare the results from this study with the extant literature, one should not neglect non-wage spending completely. As discussed above, the number of school locations may be considered as a proxy variable for non-wage spending in primary education, although it is certainly not perfect.

Thus, we have to disentangle the elasticity of wage and non-wage spending $\alpha_{(W+NW)/T,St}$. This can be accomplished by weighting the separate elasticities $\alpha_{W/T,St}$ and $\alpha_{NW/T,St}$ with the respective spending shares from Länder budgets, which gives a correct approximation if the spending shares remain constant over the considered time period. This holds for the sample period. Thus, in Equation (4), λ is the spending share of staff expenditure in the education budgets of the Länder. Over the 1993-2006 period, λ is 0.88.[14]

(4) $$\alpha_{E/St,St} = (1-\lambda)\alpha_{NW/T,St} - \alpha_{Tt/T,St} - \alpha_{St/Cl,St} + \alpha_{Tt/Cl,St}$$

Note that while Equation (4) allows us to study the *composition* of resource adjustments, an alternative and more precise way to measure the *magnitude* of resource adjustment is given by again considering Equation (1) and cancelling down (T/Tt)*(Tt/Cl)*(Cl/St) to (T/St), the teacher/student-ratio, which is considered to be a good resource indicator. An alternative, more compact, decomposition is thus obtained

(5) $$\alpha_{E/St,St} = (1-\lambda)\alpha_{NW/T,St} + \alpha_{T/St,St}$$

The elasticities on the right-hand side of Equations (4) and (5) can be estimated in a straightforward way by regressing the natural log of the number of students (St) and a set of control variables on each spending component on the right-hand side of Equations (4) and (5). For Equation (5), this gives rise to the following set of equations:

(6) $$\ln\left(\frac{NW}{T}\right)_{it} = \alpha_{NW/T,St}\ln(St)_{it} + X'_{it}\Gamma_{NW} + \eta_i^{NW} + v_{it}^{NW}$$

$$\ln\left(\frac{T}{St}\right)_{it} = \alpha_{T/St,St}\ln(St)_{it} + X'_{it}\Gamma_{TSt} + \eta_i^{TSt} + v_{it}^{TSt}$$

The elasticities of Equation (4) are estimated similarly, e.g. for class size we specify

(7) $$\ln\left(\frac{St}{Cl}\right)_{it} = \alpha_{St/Cl,St}\ln(St)_{it} + X'_{it}\Gamma_{SC} + \eta_i^{SC} + v_{it}^{SC}$$

While i denotes the Länder, t denotes the years from 1993 to 2006. The coefficients of interest are the student elasticities α. Each separate equation gives the student elasticity for a single component of education spending; the overall effect of varying student numbers on education spending per student (E/St) is given by the sum of the elasticities over the two equations (see Equation 5) or over the four equations (see Equation 4). Note that $\alpha_{NW/T,St}$ is weighted by (1-λ). Note also that $\alpha_{T/St,St}$ should prove to be identical to $-\alpha_{Tt/T,St} - \alpha_{St/Cl,St} + \alpha_{Tt/Cl,St}$.

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[14] This share refers to general school spending, not spending on primary education, since the latter is unavailable on a comparable basis.

As motivated above, non-wage spending (NW) is approximated by the number of primary school locations. With regard to the student variable, all students (St) in primary education from first to fourth grade are taken into account. X_{it} denotes a vector of control variables, which is fairly standard in the literature (see, for example, Baum and Seitz, 2003). Hence the fiscal capacity of the Länder is controlled for by including the natural log of public revenue per capita (PR) at the Länder level. Owing to the strong fiscal equalisation system across German Länder, public revenue is preferred to GDP (which may eventually be considered a better proxy for the individual preferences for schooling), because it is a much more appropriate measure of the public resources at the Länder level, which is relevant in Germany given the dominance of the public sector in the education system. Public revenue is deflated using the government consumption deflator. Accounting for the settlement pattern of the Land (natural log of population density, PD) is necessary, because school location density cannot decrease arbitrarily; especially in primary education the Länder must assure certain standards with respect to school access and the distance to school. Accomplishing this task is more difficult in the less densely populated Länder. The Länder unemployment rate (UR) is included to control for the overall socio-economic background. Additionally, we control for the share of foreign students (FS), which is a relevant variable in the West German Länder, whereas in East Germany the share of foreign students is rather small. The equations for the East German Länder are nevertheless estimated including the share of foreign students to allow for comparisons with the West German regression results. Furthermore, following the literature, the share of Länder residents older than 60 years is included (o60), which roughly represents real retirement age in Germany in the sample period. However, no a priori hypothesis regarding generational conflict is formulated, since primary education represents only a fraction of the education system at the Länder level, and Baum and Seitz (2003) find only very weak evidence pointing towards generational conflict when considering the total education sector. The number of students (St), public revenue (PR) and population density (PD) enter the model as natural logarithms, while the unemployment rate (UR), the share of foreign students (FS) and the elderly share (o60) are expressed as shares. This permits an elasticity-interpretation of all coefficients.

Länder effects η_i are included to control for Länder-specific spending preferences in education or Länder-specific administration of public schools. This unobserved Länder-heterogeneity can be assumed to stay constant over time, but it cannot be assumed to be uncorrelated with explanatory variables, i.e. public revenue per capita or population density. Thus, the η_i are treated as fixed.

In the literature it is standard to include year-specific effects to account for common shocks/trends, which capture economy-wide changes/trends in the preferences for public education spending or changes in the federal legislation that cause common shifts in spending. Since the considered time period is rather short, these effects should generally be of minor importance. We note that accounting for common shocks is particularly difficult in the regression for East Germany, because within-Länder variation in student numbers is highly correlated (see the evidence presented in Section 3). Thus, there is a problem of strong multi-collinearity between the year fixed effects and the variation in student cohort size (see, for example, Arellano, 2003, 61 or Poterba, 1997, 54). However, it is well known that not accounting for confounding macro-level trends is also problematic. Regressions are therefore also estimated including time dummies (reported in the appendix). Joint significance of the year dummies is tested using an F-test albeit the null of joint insignificance of these effects is likely to be rejected *owing* to the high correlation of variation in student numbers across the East German Länder.

The v_{it} are assumed to be independent of the η_i. However, it is not sensible to rule out serial correlation. The Wooldridge test for serial correlation in panel data models (Wooldridge, 2002 and Drukker, 2003) indicates that serial correlation is present in four out of five equations. Wooldridge (2002, 2003) suggests first-differencing of the equation when serial correlation in levels is present or non-stationarity becomes a concern.[15] This applies in particular to the $N<T$ environment. First-differencing wipes out the Länder-specific effects in Equations (6) and (7) and eliminates strong first-order serial correlation. The first-differenced equation can then be estimated by simple OLS, which is called the First Difference (FD) estimator (Wooldridge, 2002). Standard errors are estimated robust in the presence of heteroskedasticity and remaining (weak) serial

dependence using the correction of the autocovariance matrix as suggested by Newey and West (1987) (see also Arellano, 2003).[16]

4.3 Estimation results

This section first presents evidence on the *magnitude* of resource adjustments in East Germany by reporting the results from the T/St and NW/T regressions and by comparing these results to similar evidence for the West German Länder. The *structure* of the resource adjustment is investigated in more detail in Section 4.3.2 by performing regressions on the single components of the teacher/student-ratio, while Section 4.3.3 is an attempt to evaluate the *educational effectiveness* of the adjustment package. Finally, Section 4.3.4 reports additional evidence from a reduced sample which only considers data from years in which student cohort size actually decreases (1993-2002).

4.3.1 The magnitude of resource adjustments

Table 2 presents the results for the East German Länder. Similar models including year fixed effects are reported in Appendix 2. The regression estimated for school locations per teacher (NW/T) suggests a student elasticity of about -0.23, while the model including year fixed effects yields a coefficient of -0.12, which is not significantly different from zero (see left column of Appendix 2). The F-test confirms joint significance of the year fixed effects at the 5% level. This is not too surprising given that the demographic variation is highly correlated across the East German Länder, as discussed in Section 3. Thus, a clean identification of the effect from decreasing student cohort size in the presence of year fixed effects is indeed not possible. The model without time dummies is therefore the preferred model and the student elasticity of school infrastructure per teacher should be around -0.2.

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[15] Testing for stationarity is difficult owing to the low power of unit root tests for a short time series dimension.

[16] With regard to the estimation techniques, one issue deserves further comment. The system of equations shown in (6) and (7) could in principle be estimated by SUR. Compared with single-equation-OLS, efficiency gains could be achieved if errors across equations were highly correlated and if correlation between the regressors over the equations were low. However, in the present study, the set of regressors is identical over the equations; thus SUR is equivalent to OLS. In addition, efficiency gains are arguable in small sample applications (Greene, 2003, 343 and 413).

Table 2: Regression results (5 East German Länder, 1993-2006)

	Δ ln(NW/T)	Δ ln(T/St)
Δ ln(St)	-0.232	-0.506
	(0.128)*	(0.138)***
Δ ln(PR)	0.088	-0.067
	(0.164)	(0.146)
Δ ln(PD)	3.636	-1.498
	(0.974)***	(0.956)+
Δ UR	0.685	-0.759
	(0.376)*	(0.452)*
Δ FS	6.277	-3.841
	(3.270)*	(3.620)
Δ o60	1.517	-1.974
	(3.527)	(3.109)
Constant	0.001	-0.002
	(0.020)	(0.016)
Observations	65	65
Adjusted R-squared	0.54	0.44

Note: Robust standard errors are reported in parentheses (Newey and West, 1987). ***, **, * and + denote significance at the 1%, 5%, 10% and at the 20% level, respectively. Year fixed effects are excluded (see text).

The right-hand column of Table 2 reports the student elasticity of the teacher/student-ratio (T/St), which is about -0.5 and significantly different from zero at the 1% level. This elasticity suggests that the long-run 50% decrease in student numbers is accompanied by a 25% increase in the teacher/student-ratio, which corresponds to the descriptive evidence presented in Figure 4 (a). In contrast, the model including year-specific effects (see right column of Appendix 2) suggests an insignificant student elasticity of the teacher/student-ratio. Taken at face value, the point estimate of about +0.13 implies that the teacher/student-ratio *decreases* with decreasing student numbers, which contrasts starkly with the descriptive evidence. Furthermore, there is abundant anecdotal evidence from East Germany that casts considerable doubt on the plausibility of this coefficient: For example, the East German Länder education ministries explicitly report a causal relationship of decreasing student numbers on *higher* teacher/student-ratios (Sächsisches Staatsministerium für Kultus, 2005, 2007a and 2007c). Overall, the evidence supports the concern that the effect from the demographic variation may not be identified in the presence of year dummies. Thus, the model without year fixed effects is the preferred model, which suggests a student elasticity of around -0.5.

The control variables yield mostly similar coefficients over the models including and excluding year fixed effects in the NW/T and T/St regressions, with the exception of real public revenue per capita (PR). This suggests the interpretation that, besides the highly cross-Länder-correlated student variation, the year dummies cancel out common shocks in Länder public revenue. Here, it is plausible that the time effects capture economy-wide business cycle effects since one important feature of the fiscal equalisation scheme across the German Länder is that individual Länder revenues are highly sensitive to business cycles affecting the overall economy, but much less so to Länder-specific shocks (Baretti, Huber and Lichtblau, 2002). The year effects may also capture changes in the magnitude of the federal grants to the East German Länder used to finance the reconstruction of the public capital stock. Furthermore, population density is an important determinant of the number of school locations per teacher, which reflects the fact that school density cannot decrease arbitrarily, given that primary students are not expected to walk/drive long distances to school.

Table 3: Regression results (8 West German Länder, 1993-2006)

	Δ ln(NW/T)	Δ ln(T/St)
Δ ln(St)	-0.626	-0.542
	(0.255)**	(0.077)***
Δ ln(PR)	0.113	0.028
	(0.295)	(0.027)
Δ ln(PD)	5.064	0.382
	(3.878)+	(0.376)
Δ UR	-0.078	-0.658
	(0.798)	(0.223)***
Δ FS	0.912	-0.079
	(2.584)	(0.705)
Δ o60	3.990	-2.309
	(2.002)**	(0.797)***
Constant	-0.032	0.011
	(0.014)**	(0.003)***
Observations	104	104
Adjusted R-squared	0.07	0.55

Note: Robust standard errors are reported in parentheses (Newey and West, 1987). ***, **, * and + denote significance at the 1%, 5%, 10% and at the 20% level, respectively. Year fixed effects are excluded (see text).

Table 3 presents the results for the West German Länder without year effects, while the results including year effects are reported in Appendix 3. The elasticity of school infrastructure per teacher is estimated with -0.63, which suggests that resource adjustment in West Germany is considerably lower than in the East German Länder. This result is not surprising given that the adjustment of school infrastructure involves considerable costs and the variation in student numbers is quite low over the sample period in West Germany. The inclusion of year fixed effects (see Appendix 3) yields a coefficient which is not significantly different from zero and which contrasts starkly with the coefficient estimated for the model without year effects, which is difficult to interpret, and may even be spurious owing to the limited within variation. The year fixed effects are, however, not even jointly significant in the estimations for West Germany. Therefore, the models including year dummies are not considered further. The student elasticity of the teacher/student-ratio is estimated at -0.54, which suggests that resource adjustment in West Germany is less responsive to changes in the size of the student cohort, although the differences between East and West German Länder are small and not significantly different from zero.

Table 4 presents total student elasticities of education spending per student $\alpha_{E/St,St}$ for East and West Germany. Although the point estimates suggest that there is a difference in resource adjustments between East and West German Länder, this difference is rather low (about 0.1). In the case of the T/St regression, the differences are not significant. Significant differences between East and West German Länder arise only in the adjustment of schooling infrastructure. [17]

[17] When comparing the results for West Germany with the elasticities presented by Baum and Seitz (2003), the elasticity from the present study (-0.62) seems prima facie to be somehow low. The correct standard of comparison is the Länder level estimate from Baum and Seitz (2003) (-0.75 to -0.78). There are, however, several factors that can explain this difference besides the fact that the considered time period is different (1978-1999 vs. 1993-2006). First, the estimate of the present study could be imprecise since it is based on physical resource indicators. Second, Baum and Seitz (2003) focus on education spending as an aggregate of primary schools, lower secondary schools, higher secondary schools and vocational training. This difference could per se be a reason for a different elasticity but, in addition to that, in Baum and Seitz (2003), rising participation rates, such as in Gymnasien, may be one of the reasons that contribute to their result, as long as these rising participation rates are not entirely identical across the Länder (if so, rising participation is captured by the year dummies). Moreover, if one considers the estimate obtained from the model including year fixed effects, as shown in Table 3, Column (4), the estimated elasticities are similar (-0.77).

Table 4: Overall student elasticity of education resources in East and West Germany

Sample	Estimator	Student elasticities of education resources		
		overall	components	
		$\alpha_{E/St,St}$	$\alpha_{NW/T,St}$	$\alpha_{T/St,St}$
East	FD w/o year FE	**-0.54**	-0.23* (0.13)	-0.51*** (0.14)
West	FD w/o year FE	**-0.62**	-0.63** (0.26)	-0.55*** (0.08)

Note: Standard errors in parentheses. Point estimates, standard errors and significance levels are taken from Tables 2 and 3. The overall elasticity is calculated according to Equation (5).

Thus, compared with the evidence presented in Poterba (1997), the estimates suggest that resource adjustments in the East German Länder have been considerable. However, when comparing the East German elasticity with the results obtained from similar regressions on West German data (and with the results reported in Baum and Seitz, 2003 or Grob and Wolter, 2007), resource adjustments in East Germany appear to be only slightly larger and not significantly different from adjustments in the demographically more stable West Germany. We cannot speak of significant differences, also because we cannot entirely rule out that the East German Länder in the post-transition period enjoyed somewhat more discretion in policy-making with respect to human resources management, and because we cannot either rule out entirely that we slightly underestimate the true elasticity owing to the use of physical resource indicators (although Weiß and Weishaupt, 1999 and Sackmann et al., 2009 suggest that this has not played a major role). The estimates suggest that the 50% decrease in the size of student cohorts in East Germany has translated into a 25% increase of spending per student. In other words, if the East German Länder had adjusted education resources with the elasticity of their West German counterparts, education spending per student would have risen by about 30%. However, given the higher variation in East Germany, we note that a similar elasticity observed in East and West Germany may imply much stronger resource adjustments (in terms of the share of teaching capacities) in the Eastern Länder.

4.3.2 The composition of resource adjustments

The teacher/student-ratio may be decomposed further to identify the sources of increased resource use per student. Additional regressions are estimated for East

Germany (see example in Equation 7). Table 5, Columns (1), (2) and (3) report the estimates for the student elasticities of teaching time per teacher (Tt/T), class size (St/Cl) and teaching time per class (Tt/Cl), respectively. For the reasons discussed above, only the models without year dummies are reported (The results including year fixed effects are available upon request, see also footnote 19).

Table 5: Regression results (East German Länder, 1993-2006)

	(1) Δln(Tt/T)	(2) Δln(St/Cl)	(3) Δln(Tt/Cl)
Δ ln(St)	0.256	0.221	-0.029
	(0.169)+	(0.039)***	(0.077)
Δ ln(PR)	-0.097	0.076	-0.089
	(0.164)	(0.030)**	(0.128)
Δ ln(PD)	0.776	0.576	-0.146
	(1.011)	(0.261)**	(0.880)
Δ UR	0.181	0.087	-0.491
	(0.351)	(0.119)	(0.282)*
Δ FS	4.734	0.015	0.908
	(5.524)	(1.163)	(3.286)
Δ o60	0.146	0.737	-1.091
	(4.282)	(0.688)	(2.840)
Constant	0.014	0.003	0.015
	(0.022)	(0.003)	(0.018)
Observations	65	65	65
Adjusted R-squared	0.02	0.81	0.00

Note: Robust standard errors are reported in parentheses (Newey and West, 1987). ***, **, * and + denote significance at the 1%, 5%, 10% and at the 20% level, respectively. Year fixed effects are excluded (see text).

Teaching time per fte teacher appears to be an adjustment instrument in East Germany (elasticity of 0.25, close to 10% significance).[18] Class size is also part of the adjustment package (highly significant elasticity of -0.22).[19] In the Tt/Cl regression, the number of

[18] Note that the effect works independently of part-time agreements made between the East German Länder and teacher unions during the sample period (primary school teachers in many Länder agreed to work about 70% of their normal working hours, i.e. they earn wages that are proportionately lower). The effect described above applies to *fte* teacher capacity and, thus, is at work independently of any working-time reduction that is accompanied by a proportionate reduction in teacher wages.

[19] The models including year effects (available upon request) suggest for both the Tt/T and St/Cl regressions considerably different estimates of the student-elasticities (-0.26 for the Tt/T regression and -0.06 for the St/Cl regression). As discussed above, this is not surprising and can be explained by highly correlated student variation, which makes identification of the effect of student cohort size on education resources virtually impossible. Consider, for example, the St/Cl regression: taken literally, the point estimate of the specification including year fixed effects suggests that decreasing student numbers induce larger class size, but this is highly implausible given the descriptive evidence shown in Figure 3.3 (a) and anecdotal evidence from East German Länder education ministries (Sächsisches Staatsministerium für Kultus, 2007b and 2007c).

students yields only quite small and insignificant coefficients. This suggests that teaching input per class has not been increased with redundant teaching capacity, or increased only to a limited extent. This result implies that increased teaching input per class (see Figure 4 a) is independent of shrinking student cohorts. Summarising the student elasticities for the single components of education spending for East and West Germany, Table 6 permits a comparison of the composition of resource adjustments under conditions of rapid demographic change with policy responses in demographically more stable periods. A first finding is that summing the student elasticities of the single components of education spending according to Equation (4) matches the elasticity of the teacher/student-ratio quite well (compare Tables 4 and 6).

Table 6: Overall student elasticities of single physical resource variables in East and West Germany

Sample	Estimator	Student elasticities of education resources				
		overall	components			
		$\alpha_{E/St,St}$	$\alpha_{NW/T,St}$	$\alpha_{Tt/T,St}$	$\alpha_{St/Cl,St}$	$\alpha_{Tt/Cl,St}$
East	FD w/o year FE	**-0.54**	-0.23* (0.13)	0.26+ (0.17)	0.22*** (0.04)	-0.03 (0.08)
West	FD w/o year FE	**-0.62**	-0.63** (0.16)	0.00 (0.12)	0.35*** (0.06)	-0.19 (0.14)

Note: Standard errors in parentheses. Point estimates, standard errors and significance levels are taken from Table 3.5 and from similar regressions for West Germany (available upon request). The overall elasticity is calculated according to Equation (4).

The general message from the decomposition is that the adjustment bundles differ considerably between the East and the West German Länder. *First*, as discussed above, school infrastructure per teacher has been adjusted considerably to falling student numbers in East Germany; note the large difference between the estimates for West and East Germany. *Second*, the adjustment of class size is significantly higher in the East German Länder. The point estimate obtained from East German data is about 2/3 of the West German estimate. Taken literally, the estimated elasticity of 0.22 implies that class size drops by about 10% in the course of the 50% decline of student cohorts, which roughly corresponds to the descriptive evidence (see Figure 4 a). *Third*, there is also a large difference between the student elasticities of teaching time per teacher in East and West Germany. In West Germany, this elasticity is virtually zero, whereas the elasticity is estimated to be around 0.25 for the East German Länder. This suggests that the East German Länder use teaching hours per teacher as an adjustment instrument for redundant teaching capacity. Given the definition of the variables teaching time (Tt) and fte teachers (T) - see also the discussion in Section 3 - another possible interpretation is that the East German Länder increase spare capacity (Vertretungsreserven), i.e. more substitute teachers have been held available to prevent cancellation of teaching time due to the absence of regular teachers. Note that this effect is large: the estimated elasticities imply that the ratio Tt/T has been reduced by about 12% ceteris paribus. Both interpretations may be valid, i.e. teaching hours per fte teacher are reduced and a larger spare capacity of substitute teachers has prevented the cancellation of instructional time. Anecdotal evidence from Saxony, the largest East German Land, suggests that cancelled teaching time in primary schools dropped by almost 50% from 1995 to 1999. Moreover, cancelled time was at a very low level in primary schools: in 1999, about 0.6% of total instructional time was cancelled, compared with 3.2% in secondary education and 7.5% in vocational training courses (Sächsischer Landtag, 2000).[20] *Finally*, as discussed above, the estimation results suggest that teaching time per class has not been increased with redundant teaching capacity in East Germany. Again, this is different in West Germany, where an elasticity of about -0.2 is estimated, suggesting that the West German Länder increase/decrease teaching time per class with variations in the size of the student cohort.

4.3.3 The educational effectiveness of resource adjustments: a tentative evaluation

The following discussion represents a rudimentary attempt to evaluate the educational effectiveness of the adjustment package.

We observe that the elasticity of class size to shrinking student cohorts is considerably lower in the East German Länder, which accounts for an important part of the difference between East and West Germany. On the one hand, the results from the education production function literature suggest that the effect of smaller classes on student performance is limited. On the other hand, as stated by Coates (2003), the combination of smaller classes and increased teaching time per class can be an effective way of spending schooling resources in primary education. The estimation results strongly suggest that redundant teaching capacity is not used to increase teaching input per class.

[20] In Saxony, teaching time per teacher (Tt/T) drops by about 6% from 1993 to 1994. In 1999 (2002), teaching loads per teacher are about 7% (17%) below the 1993 level.

However, teaching time per class increases during the sample period (see Figure 4 a), obviously for reasons other than the declining student cohort and subsequently abundant teaching capacity. Thus, after all, students may indeed benefit from smaller classes owing to the combination of moderately smaller classes with increased teaching time per class.

The results for the student elasticity of teaching time per fte teacher lead to some ambiguity. As stated above, there are two possible interpretations which imply quite different conclusions from the view of educational effectiveness. On the one hand, less teaching time per teacher may be caused by increased spare capacity and less cancellation of teaching time. This interpretation is supported by descriptive evidence, which shows that the loss of instructional time in East German primary education in the early 2000s is low when compared with (i) previous years, (ii) secondary education and (iii) the West German Länder. Reducing the cancellation of classes may be considered a comparatively effective way of spending resources, although this result is not undisputed and gains may be limited. On the other hand, the student elasticity of teaching time per fte teacher is quite large, which suggests that a portion of the additional resources may be due to a reduction in teaching loads per teacher.

Overall, the adjustment package in the East German Länder probably contains some demographic costs, i.e. increased education spending per student that cannot be expected to be a substantial investment in human capital formation (e.g. decreased teaching hours per fte teacher, reduced class size, etc.). However, there is also some fraction of increased spending per student which can be assumed to translate into better student performance in the future (less cancellation of instructional time, a combination of smaller classes and increased teaching time per class, etc.).

4.3.4 Isolating the demographic shock: evidence from the 1993-2002 period

Figure 3 (a) shows that whereas the number of school locations falls throughout the sample period, the number of students and teachers stagnates in 2002 and begins to rise again in 2004. This finding produces some concern that the sample period may be too *long* to yield clean estimates of education policy in the years of decreasing student numbers. Therefore, we re-estimate Equations (6) and (7) for the 1993-2002 period, bearing in mind that, by doing so, we further reduce the (already quite small) sample. We suggest that the results from the reduced sample are more adequately viewed as a complement to the estimates for the full sample period. Table 7 reports the results for all spending components in the East German Länder over the 1993-2002 period.

The lesson to be learned from the estimations based on the shorter sample period is quite clear. Noting a significantly smaller student elasticity of the *teacher/student-ratio* (-0.2) compared with the full sample period and compared with the West German Länder indicates that teaching capacity is adjusted considerably in the period of the strongest decrease in student numbers up to 2002. Figure 4 (a) shows this is true especially up to 1998 when the teacher/student-ratio increases only to about 5% above the 1993 level, while student numbers have already decreased by about 30%. The elasticities estimated for *teaching time per teacher* (Tt/T), *class size* (St/Cl) and *teaching time per class* (Tt/Cl) are not significantly different from the elasticities estimated for the full sample period, but the point estimates tend to be smaller than the full-sample results. In particular, the smaller student elasticity of teaching time per teacher (Tt/T) accounts for about two thirds of the difference between the 1993-2006 estimate and the 1993-2002 estimate. In summary, the resource adjustments are considerable in times of shrinking cohort size but are not carried much further in the following years.[21]

For *school infrastructure*, the adjustment is less strict when looking at the shorter period (-0.49) compared with the full sample period until 2006 (-0.23), which is consistent with the view of sluggish adjustment problems. Apparently, Länder and Gemeinden (local governments) face problems of sluggish adjustment in the provision of school buildings and this adjustment takes more time than for teaching capacity. Consequently, the overall student elasticity of education spending per student for the 1993-2002 period is given by about $-0.21 + \lambda\,(-0.49) = -0.27$.

Yet, these findings are inconsistent with the view that the East German Länder experience major problems in adjusting the number of fte teachers. Rather, the adjustment of teaching capacity begins quickly and stops early. Figure 3 (a) reveals that

[21] This result could theoretically be influenced by a decreasing intensity of the use of early retirement schemes for teachers in East Germany. However, early retirement was of relatively little importance in East Germany and thus, cannot explain significant parts of the differences (see Sackmann et al., 2009).

teaching capacity is significantly adjusted only up to 2000, when student cohorts are still decreasing. Thereafter, teacher employment stagnates and begins to increase in 2004. We would expect the number of teachers to continue decreasing even beyond 2000 if there were major problems in adjusting teaching capacity to decreasing student cohort size. Consequently, a large part of the inelastic response estimated for the 1993-2006 period is rooted in the post-2000 period owing to causes other than teacher employment protection.[22] [23]

Table 7: Regression results (5 East German Länder, 1993-2002)

	(1) Δ ln(NW/T)	(2) Δ ln(T/St)	(3) Δln(Tt/T)	(4) Δln(St/Cl)	(5) Δln(Tt/Cl)
Δ ln(St)	-0.487 (0.143)***	-0.206 (0.121)*	0.042 (0.150)	0.164 (0.054)***	0.000 (0.128)
Δ ln(PR)	0.161 (0.155)	-0.123 (0.135)	-0.114 (0.170)	0.091 (0.028)***	-0.146 (0.132)
Δ ln(PD)	3.752 (0.903)***	-2.467 (0.882)***	1.822 (1.256)+	0.852 (0.306)***	0.207 (0.919)
Δ UR	0.666 (0.423)+	-0.794 (0.457)*	0.288 (0.287)	0.155 (0.127)	-0.351 (0.235)+
Δ FS	4.377 (4.066)	-3.897 (4.577)	1.604 (4.910)	0.050 (1.473)	-2.244 (2.553)
Δ o60	-6.306 (6.334)	8.036 (6.280)	-4.653 (6.231)	-0.063 (2.291)	3.321 (4.262)
Constant	0.034 (0.038)	-0.044 (0.037)	0.037 (0.034)	0.002 (0.011)	-0.004 (0.019)
Observations	45	45	45	45	45
Adjusted R-squared	0.38	0.40	0.00	0.72	0.00

Note: Robust standard errors are reported in parentheses (Newey and West, 1987). ***, **, * and + denote significance at the 1%, 5%, 10% and at the 20% level, respectively. Year fixed effects are excluded (see text).

[22] It is not clear whether this result easily generalises to West Germany since the structure of teacher employment is different between East and West Germany (see Section 2.3). In West Germany, many teachers are public servants who enjoy special employment protection. Furthermore, eventually, the East German Länder still had somewhat more discretion in policy-making after 1993 (during the transition of the education system) although Weiß and Weishaupt (1999) suggest that this was not the case.

[23] To check whether teacher employment protection was any problem for the Länder governments, we may estimate models as in Equation (6) and (7) but containing leaded student numbers in addition to contemporaneous student numbers. Cohort size is known with certainty about 6 years in advance. If Länder governments face some difficulties in cutting teaching capacity, it is rational for them to begin the adjustment process in advance. In such models, leaded values of student numbers yield significant coefficients in the regressions of the teacher/student-ratio (at the 20% significance level) and of class size (at the 5% significance level). The results show that in both models about 30% of the adjustment response may have been initiated one period in advance, which in turn suggests that Länder governments in East Germany face at least some restrictive employment protection in the adjustment process.

A political-economic interpretation of this result is that Länder governments have an easier task explaining the need to cut teacher employment in times of dramatic losses in the number of students. This becomes much more difficult as soon as student numbers stagnate or begin to increase. Specifically for the post-2001 period in Germany, politicians may have faced problems in explaining resource cuts in public education due to the "PISA-Schock" in 2001. The publication of the German PISA results by the OECD in autumn 2001 is somewhat comparable to the "Sputnik crisis" in the U.S. in the late 1950s. At the time, the PISA results revealed that the German education system was not as good as commonly believed, and created pressure on policymakers to improve learning conditions and maintain the same educational levels as other industrialised countries. Public opinion may have complicated the implementation of further resource adjustments in public education. Typically, one should try to control for the "PISA-Schock" by introducing time effects into the model, which is impossible owing to the difficulties with the time effects described above. Thus, we cannot easily claim that the results are net of possible changes in public education demanded by parents, political factions and the like following the publication of the PISA results.

5 Conclusions

Previous empirical evidence for several countries on the link between school spending and student cohort size suggests that total education spending is not adjusted proportionately to varying sizes of the student cohort. According to these results, a large decrease in the student cohort should translate into an important increase in education spending per student rather than into a significant decrease in resources allocated to public education. This paper attempts to test whether this result holds true under conditions of rapid demographic change using panel data on primary education in the five East German Länder (1993-2006) where the birth rates collapsed after the fall of the Iron Curtain in 1990. An advantage of using data on primary schools is that the estimation results are not biased by increasing participation rates which may distort elasticities estimated for higher levels of education. To evaluate what rising education expenditures per student actually finance, education spending per student is decomposed into physical resource indicators such as class size, etc.

We find that resource adjustment in the East German Länder appears to be particularly strong in times of decreasing student cohorts (1993-2002). The data for this period suggests a student elasticity of education spending per student of about -0.27, which is considerably smaller than the state-level estimates from the literature, which range from about -0.6 to -1.0. This finding is remarkable, given that already a similar elasticity observed in East and West Germany implies strong resource adjustments in the East German Länder owing to high variation in student numbers. Apparently, adjustment efforts faded in the following years when student numbers stagnated and began to increase later. The data for the full period (1993-2006) suggests a student elasticity of education spending per student of -0.54. This elasticity is still smaller than most results from the literature, but not significantly different from the elasticity estimated for the demographically more stable West Germany (-0.62). Overall, our estimation results imply that the 50% decline in primary school students caused education spending per student in East Germany to increase by about 27%.

One plausible interpretation of the fading adjustment efforts after 2001 is that Germany's politicians faced increased resistance from pressure groups such as teachers' unions and parents in times of stagnating or increasing student cohort size. In particular, in 2001 when student numbers had begun to stagnate, publication of the PISA results in the autumn had considerable repercussions for the public debate, and may have shifted spending preferences for public education upward. Hence, it cannot be ruled out that fading adjustment efforts after 2001 are confounded with effects from the "PISA-Schock". In some sense, the evidence found for the reduced sample (1993-2002) may be "cleaner" from confounding factors and we may conclude that there is some evidence pointing to sharper resource adjustments during times of strong and rapid demographic change.

As to the underlying adjustment mechanism, the findings from the reduced sample challenge the view that the East German Länder experienced major problems in adjusting teaching capacity owing to teacher employment protection (at least with the East German model of teacher employment). This finding supports the assumption that the public sector is capable of adjusting its budget structure to changes in the demographic composition of the population (e.g. as in Seitz and Kempkes, 2007).

The decomposition of spending per student identifies the channels of increased resource use per student. Somewhat surprisingly, an important fraction of the increase is caused by declining teaching load per teacher. This effect is large and has two possible sources: either teaching loads per teacher were reduced or the Länder increased spare teaching capacity to prevent teaching time from being cancelled due to unexpected absences of teachers. Decreasing class size contributes only moderately to rising expenditures per student when compared with the West German Länder, but still accounts for an important fraction of increased spending per student. Teaching time per class steadily increased over the sample period; however, the estimates suggest that this increase was independent of the decreasing size of the student cohorts. A brief survey of relevant results from the literature of education production functions suggests that this adjustment package contains not only some fraction of demographic costs but also investments in human capital formation which may translate into improved student performance. In fact, there is some anecdotal evidence; in the 2006 PISA test, the East German Länder considerably improved their performance compared with earlier editions of the test. In particular in 2006 (2001), three (two) East German Länder ranked among the top five in mathematics (*Saxony*, *Thuringia* and Mecklenburg-Vorpomerania), three (one) in sciences (*Saxony*, Thuringia and Saxony-Anhalt) and two (one) in reading (*Saxony* and Thuringia). The students who were tested in 2006 (grade 8) left primary schools in 2002. Thus, they may have benefited from more generous resource endowments in primary school.

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Appendix 1: A brief literature review from the economics of education

Based on the results of educational production economics, the spending elements on the right-hand side of Equation (1) can be assessed briefly with respect to educational effectiveness. The effect of *class size* (St/CL) on student performance has been extensively investigated in recent years (Hanushek, 1986; Card and Krueger, 1992; Hoxby, 2000 or Wößmann and West, 2006). The prevailing opinion appears to be that smaller class size does not per se lead to higher student performance. Less evidence is available on the effect of *teaching time per class* (Tt/Cl) or per student on educational achievement. Yet, most studies suggest that there is no simple mechanism that associates more instructional time with much higher student achievement (for surveys see Millot and Lane, 2002 or Baker et al., 2004). However, most studies find at least small beneficial effects of more teaching time on outcomes. This is true especially when more teaching time is combined with reduced class size (Coates, 2003). *Cancellation of instructional time* seems to have negative effects on student performance (Marcotte and Hemelt, 2007). Obviously, this effect is only partially offset if substitute teachers cover the time (Clotfelter, Ladd and Vigdor, 2007). With respect to *teaching time per teacher* (Tt/T), to our knowledge, no study exists that shows a beneficial/harmful effect on student performance. Given that teaching obligations and teacher salaries in primary education are well within the framework given by the OECD countries (OECD, 2004, 390 and 407), there are no a priori reasons to suspect beneficial/harmful effects of decreasing teaching loads per teacher. The proxy variable of non-wage spending per teacher (NW/T), namely the number of school locations per teacher, closely links to school size and way to school. Kuziemko (2006), Foreman-Peck and Foreman-Peck (2006) as well as Jones, Toma and Zimmer (2008) find that students in smaller schools skip lessons less frequently and achieve higher test scores. However, one should bear in mind that the number of schools is used as a proxy for non-wage spending at the Länder level. Recall that school infrastructure is a responsibility of the municipalities. In summary, decreasing class size and additional teaching time per class may have (small) beneficial effects on student achievement, especially in combination with each other. Also, the availability of substitute teachers and thus refraining from cancelling instructional time may be considered a (limited) investment in human capital. No such effect can be assumed for decreasing teaching time per teacher.

Appendix 2: Regression results (5 East German Länder, 1993-2006)

	Δ ln(NW/T)	Δ ln(T/St)
Δ ln(St)	-0.122	0.132
	(0.554)	(0.458)
Δ ln(PR)	-0.579	0.667
	(0.373)+	(0.409)+
Δ ln(PD)	3.015	-1.815
	(1.240)**	(1.177)+
Δ UR	1.508	-1.995
	(1.281)	(1.153)*
Δ FS	8.160	-8.052
	(3.914)**	(4.133)*
Δ o60	1.087	1.121
	(6.132)	(5.228)
Constant	0.024	-0.025
	(0.033)	(0.032)
Observations	65	65
Year FE?	Yes	Yes
F (Year FE)	2.60**	3.46***
Adjusted R-squared	0.54	0.50

Note: Robust standard errors in parentheses (Newey and West, 1987). ***, **, * and + denote 1%, 5%, 10% and 20% significance levels, respectively. Joint significance of the year effects tested with an F test.

Appendix 3: Regression results (8 West German Länder, 1993-2006)

	Δ ln(NW/T)	Δ ln(T/St)
Δ ln(St)	0.981	-0.687
	(1.405)	(0.274)**
Δ ln(PR)	0.136	0.008
	(0.355)	(0.029)
Δ ln(PD)	2.757	1.027
	(2.896)	(0.822)
Δ UR	0.047	-0.518
	(2.046)	(0.528)
Δ FS	4.364	0.272
	(4.509)	(0.901)
Δ o60	-1.654	1.523
	(5.008)	(1.879)
Constant	-0.085	0.004
	(0.057)+	(0.011)
Observations	104	104
Year FE?	Yes	Yes
F (year eff.)	0.65	0.81
Adjusted R-squared	0.07	0.53

Note: Robust standard errors in parentheses (Newey and West, 1987). ***, **, * and + denote 1%, 5%, 10% and 20% significance levels, respectively. Joint significance of the year effects tested with an F test.

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