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Catching-up of East German Labour Productivity in the 1990s

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Abstract. *We provide empirical evidence for exogenous and endogenous catching-up of East German labour productivity to West German levels. We argue that labour productivity in East Germany has caught up faster than has happened elsewhere. The sudden formation of the German Monetary Union was followed by large transfers to East Germany, migration of workers to West Germany, reorganization and privatization of East German firms. This has quickly led to a partial closing of the organizational, idea and object gaps that existed between East and West Germany. This paper analyses labour productivity in East and West Germany using both aggregate German data and unbalanced panel analysis of developments in East and West Germany. Factors affecting the organization of production, and especially privatization and 'foreign' firms, are found to be particularly important in this context.*

1. INTRODUCTION

On unification there were clear differences in the level of productivity between East and West Germany. They derived from differences in the quantity and quality of the capital stocks in the two countries, from differences in the nature and stock of human capital, and from the organization of the process of production. This paper addresses the potential convergence of labour productivity in East Germany on West German levels. We seek to answer why and how fast East German labour productivity has been converging to West German levels. We start with a brief discussion of the convergence literature in the context of German unification. We then discuss economic conditions in East Germany since unification. Our intention is to quantify the speed of catch-up in East Germany, and we discuss several frameworks in which

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this can be done. We then model the convergence of labour productivity and provide empirical results on the speed of catching-up in an exogenous and endogenous framework. We use both aggregate data for the whole of Germany and data for each of the East and the West in unbalanced panel analyses of the factors affecting labour productivity both for the economies as a whole and at the industry level.

2. CONVERGENCE IN CONTEXT

As we show below, East German labour productivity has converged on that in West Germany more slowly than was initially thought but faster than would have been expected on the basis of studies of convergence such as by Barro and Sala-i-Martin (1991). Labour productivity in the East was probably about one-third of that in the West, measured by total output per hour worked, in 1991 as can be seen from Table 1. By 1997 the gap in labour productivity had narrowed,

Table 1 Labour productivity and wages in Germany

	Labour productivity[a]					Wages[b]		
	West Germany	East Germany	Germany	East/ West	Whole/ West	West	East	East/ West
				Levels				
1991	57.00	18.78	48.97	0.33	0.86	44,430	21,458	0.48
1992	57.09	20.29	50.30	0.36	0.88	46,996	29,450	0.63
1993	57.51	22.43	51.54	0.39	0.89	48,350	34,070	0.70
1994	59.48	24.63	53.01	0.41	0.89	49,309	36,142	0.73
1995	61.54	26.18	54.88	0.43	0.89	50,859	38,527	0.76
1996	63.14	27.43	56.47	0.43	0.89	51,874	39,748	0.77
1997	65.20	29.09	58.60	0.45	0.90	52,243	40,408	0.77
				Annual growth rates				
1991	–	–	–			–	–	
1992	0.2%	8.0%	2.7%			5.8%	37.2%	
1993	0.7%	10.5%	1.7%			2.9%	15.7%	
1994	3.4%	9.8%	3.7%			2.0%	6.1%	
1995	3.5%	6.3%	3.5%			3.1%	6.6%	
1996	2.6%	4.8%	2.9%			2.0%	3.2%	
1997	3.3%	6.1%	3.8%			0.9%	1.7%	

Notes:
[a] Output in DM per employee hour (GDP expressed in 1991 prices).
[b] Annual gross wage and salaries per employee.
Source: Federal Statistics Office and IAB, see IAB (1998) and own calculations.

but it was still 55 per cent. A number of forces have been at work, and we have to understand them in order to answer questions such as how long will it take for the East to converge to Western productivity levels and whether convergence will be associated with full employment in the medium term. These issues have all been variously discussed by Akerlof *et al*. (1991), Dornbusch and Wolf (1992), Hughes Hallet and Ma (1993), Hughes Hallet *et al*. (1996) and Keller (1997).

The literature on growth and convergence is extensive, and it is discussed for instance in Romer (1996). It is generally agreed that output growth depends upon the growth of factor inputs and the rate of technical progress. Not all countries have access to the same levels of technology, and it is possible that technology can be transferred across borders. Less advanced countries catch up partly by absorbing already existing technology, and hence they converge on more advanced ones. Barro and Sala-i-Martin (1991) suggest that such convergence is slow, and only 2 per cent of any gap is closed each year. If this were the case it would take 35 years to eliminate half the gap in GDP per capita between East and West Germany. We believe that recent research has cast doubt on the validity of such slow and uniform convergence estimates. For instance, it is suggested that imposing a common rate of convergence in a panel framework leads to an underestimation of the rate of convergence if heterogeneity is present in the sample. Lee *et al*. (1997) take a commonly used panel of countries and allow for the innate heterogeneity in the dynamics. They estimate that more than 10 per cent of any technology-based gap is commonly closed each year if we make such an allowance. Funke and Strulik (1999) approach the analysis of regional inequality amongst the Länder of West Germany in a similar way. After allowing for innate heterogeneity they find that we can identify quite rapid convergence, but that each Länd converges on its own steady state, and that the ordering of rich and poor regions does not change greatly over time.

A number of Central European countries underwent radical transformation in the organization of economic activity in the early 1990s. Poland quickly adapted to the new situation and has been growing rapidly since 1991. Hungary and the Czech Republic took longer to adjust. Other countries, such as Romania, appear to be still in some difficulties. None of these transition countries increased their labour productivity as fast as East Germany. It is very likely that the situation in East Germany is different from that of the other former East European countries. In an early paper, Dornbusch and Wolf (1992) argued that greater contact, exposure and communication with high productivity West Germany differentiates the East German case. In particular it was thought that the skills and education of the workforce were such that productivity growth would be rapid. In 1988, for instance, the proportion of the workforce with qualifications was higher in the East, at 78.7 per cent, than it was in the West (72.5 per cent; see OECD, 1991, p. 20). The proportion with qualifications at apprenticeship level, the core of skills in the German economy, were virtually identical.

The existence of high levels of skills should have made the automatic absorption of new techniques easier. We can estimate the speed of absorption as exogenous catch-up in the level of technology. We will also study convergence as an endogenous process, depending on factors such as organizational change through privatization and West German ownership. Convergence can involve closing ideas and object gaps identified by Romer (1993) as well as solving the organization gap. The closing of the ideas gap is achieved by transferring technological know-how, while the closing of the object gap involves the accumulation of necessary equipment and capital for production. The closing of the organization gap implies the movement of firms towards their production possibilities frontier and hence the reduction of the *X*-inefficiency. In the case of East Germany we think that this is particularly important, as much of the low productivity in the East appears to have stemmed from poor organization. In particular, Romer suggested that multinational firms can play a special role in solving the ideas gap by letting ideas flow across national borders. Much German investment in East Germany can be seen playing a vital role in solving part of the idea, object and organization gaps. It was widely felt at the beginning of the transition that the process would be complete once the capital stock had been renewed and the structure of production reorganized. In this case convergence would have been a rapid process, albeit to some steady-state level of output that would be specific to groups of Länder, as Funke and Strulik (1999) stress.

3. ECONOMIC CONDITIONS IN EAST GERMANY SINCE UNIFICATION

Unification induced a large shock on the East German economy. The formation of German economic and monetary union at parity rendered most East German production loss-making. The demand for locally produced goods fell as East Germans shifted to 'imports', and 'exports' fell because of the disjunction of trade with former markets in the East and because prices were uncompetitive given the quality of products. The rapid rise of wages in East Germany worsened the competitiveness situation. As a result output fell rapidly. In the two years following the fall of the Berlin Wall measured real GDP in East Germany fell 42 per cent (Dornbusch and Wolf, 1992). The turnaround in net trade was paid for by large transfers from the West. However, the gradual renewal of the capital stock and a rapid reorganization of most firms, with significant shedding of labour, improved the productivity of those East German workers left in employment.

Germany attempted to cope with the shock of unification by transferring large sums of money from the richer West to the poorer East. Table 2 shows that transfers to East Germany amounted to 50 per cent of GDP in 1991, decreasing to just above 30 per cent in 1997. It is not clear that fiscal transfers can be effective in the long run. Large fiscal transfers can lead to similar

Table 2 Net transfers to East Germany[a]

	1991	1992	1993	1994	1995	1996	1997
Gross transfers	139	151	167	169	185	183	189
of which investment	22	23	26	26	34	33	32
Receipts	33	37	39	43	45	47	47
Net transfers	106	114	128	126	140	140	136
Per cent of							
German GDP	3.7	3.7	4.0	3.8	4.0	4.0	3.7
East German GDP	51.5	42.9	39.6	34.3	35.1	33.9	32.2

Note:
[a] Billion of DM unless otherwise stated.
Source: OECD (1998) *Economic Survey of Germany*.

problems as in the Italian Mezzogiorno. This region stagnated partly as a result of continued dependence on long-term finance from the Centre-North of Italy. However, Carlin and Richthofen (1994) argue that East Germany should avoid this problem because it has a different financial system. As DIW (1998) argues, the East German manufacturing sector remains buoyant, unlike that in the Mezzogiorno in the past. Boltho *et al*. (1996) are also optimistic that East Germany will not be a Mezzogiorno as (private) investment has been successfully encouraged, claims for wage equalization have been modified and wage bargaining has become more flexible.

Labour productivity initially rose rapidly, with the gap between East and West narrowing by 10 percentage points in the first five years. However, there were concerns that the Treuhand had reorganized East German firms too rapidly (Aghion *et al*., 1994), leading to too much labour shedding. East German productivity rose from 18.8 DM per hour to 29.1 DM per hour in 1997 (in constant prices) or from 33 per cent to 45 per cent of West German levels. Convergence has slowed recently, and part of our objective is to explain this.

As can be seen in Table 1, wages rose much more rapidly than productivity in East Germany after unification. This was in part inevitable, as in a city such as Berlin it would be very difficult to pay bus drivers different salaries depending upon which side of a now imaginary line they came from. However, much of the equalization of wages was driven by union agreements made in 1991 and 1992 (although they have been subsequently revised). Sinn (1999) argues that all parties involved in the wage negotiations had an interest in high wages in the East as *West* German employers negotiated with *East* German employees. It was also suggested that high wages could help East Germany's catching-up process by speeding industrial restructuring (Lindlar and Scheremet, 1998).

Public funds for infrastructure and construction have improved the infrastructure in the East and this attracted private funds from West Germany, and hence productivity growth improved significantly especially from 1991 to

1996, but there appears to have been some slowdown in late 1996 into 1998.[2] More productive West German investment had been replacing the less productive capital stock in East Germany, albeit more slowly after 1996, as can be seen from Table 3. Bellman and Brussig (1999) utilize a survey of manufacturers to investigate perceptions of the adequacy of the capital stock in the East, and they suggest that by 1998 plants located in the East were considered to have the appropriate stock of equipment, and hence any productivity problems must stem from elsewhere in the organization of production and the adequacy of the stock of skilled labour. Indeed Franz and Steiner (2000) in this issue point to the importance of workforce skills, and especially of tenure-related productive 'on the job training' amongst the workforce in the East.

The decline in relative investment, or return to more normal levels, is only one factor behind the decline in relative productivity growth in East Germany after 1996. This change has been characterized by slower productivity growth in the East than in previous years, accompanied by higher productivity growth in the West. However, as can be seen from Figure 1, the privatization process was virtually over by the end of 1996, and organizational reform (as measured by West German ownership) was slowing rapidly. We return to this issue. The potential effects of relocation from West Germany into Hungary, Poland and the Czech Republic may also have raised relative productivity growth in the West as lower productivity activities were relocated to lower-cost locations, leaving the average productivity in the West increased through compositional effects.

In late 1996 and 1997 there was a significant restructuring of support for the Eastern Länder. There was, for instance, a sharp decrease in the number of

Table 3 Investment-to-GDP ratio

	Germany	West Germany[a]	East Germany[a]
1991	0.23	0.21	0.45
1992	0.23	0.21	0.48
1993	0.22	0.19	0.46
1994	0.22	0.19	0.49
1995	0.21		0.49[b]
1996	0.21		0.46[b]
1997	0.20		0.43[b]

Notes:
[a] The Statistical Office stopped publishing separate accounts after 1994.
[b] Data derived using IFO (1998) and Statistisches Jahrbuch (1998).
Source: OECD *Quarterly National Accounts*.

2. We use ESA79 data. The Bundesbank (1999) argues that productivity growth is less over 1991–98 using the new ESA95 data. However, as of writing, ESA95 data are only available from 1991 onwards.

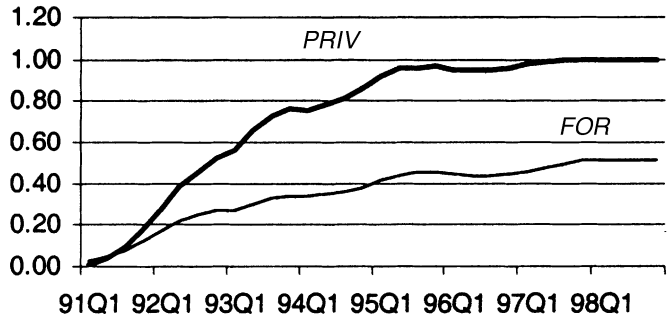

Figure 1 The share of East German employees in industrial firms in hands of 'foreign' firms (*FOR*) or in private hands (*PRIV*)
Source: DIW (1999).

people on job-creation schemes, as can be seen from Table 4. People on make-work schemes are often the least productive, or they are in the least productive places, because workers who are sufficiently productive will be able to find jobs, and jobs with high productivity will pay high wages. Indeed, the government had consciously tried to provide work experience for those with a relatively low labour productivity. Hence, this drop in the numbers of people on job-creation schemes should have increased average labour productivity through a 'batting average' effect.

There are other reasons why 1997 might be somewhat different from earlier years. The transition process really began to accelerate in Hungary, Poland and the Czech Republic in the mid-1990s, and they became an increasingly

Table 4 Explanations for a change in productivity growth in 1997

	Persons on job-creation schemes (1,000s)[a]	German FDI stock in transition countries (DM billions)[b]	Net job export (1,000s) to transition countries[c]
1991	257	2.2	63
1992	543	3.7	110
1993	365	6.3	163
1994	379	9.2	243
1995	419	13.5	345
1996	380	20.2	456
1997	298	27.5	546

Notes:
[a] Whole Germany, government schemes like ABM; see IAB (1998).
[b] *Source*: Deutsche Bundesbank, *Kapitalverflechtung*.
[c] Defined as number of jobs in German firms in transition countries minus the number of jobs in firms owned by transition countries in Germany. *Source*: Deutsche Bundesbank, *Kapitalverflechtung*.

acceptable business location. As a result over this period there was a continuing rise in employment in German firms in the core transition economies. It is likely that firms have located their least productive activities abroad in countries like Poland, Hungary and Czech Republic, relocating them from the low productivity Eastern Länder, or perhaps more importantly deciding to locate new facilities there instead of within Germany. Table 4 shows that the stock of FDI in the transition economies has increased significantly, especially since 1995, and this is a reasonable indicator of the scale of relocation.

It is also possible to scale the effect in different ways. For instance, the number of employees 'exported' to transition countries since unification has risen substantially lately, and the stock of workers in German-owned firms in the transition economies amounted to half a million in 1997.[3] IFO (1997) argues that the growth in employees in employment in West Germany in 1996 and 1997 was not as high as could have been expected given economic growth, perhaps because of this relocation of labour-intensive production to low-cost countries.

There have been a number of studies that have looked at the convergence between East and West Germany. Barro and Sala-i-Martin (1991) had a pessimistic view on convergence, and if their results were applied to this case it would take 70 years for 75 per cent of the difference to be eliminated. They ignored potential special factors affecting East Germany, such as labour and capital mobility. Hughes Hallet and Ma (1993) suggested that it would take 30–40 years to full convergence of productivity levels. Burda and Funke (1995) stressed the importance of physical capital investment in their study, and suggested it could take a generation for the process to be complete. More recent studies have been more optimistic, and Keller (1997) is among the most optimistic, with 76 per cent of the difference in output per capita being eliminated in 20 years, stressing the importance of both labour and capital mobility. That study is optimistic perhaps because it provides estimates on the basis of data over 1991–95 when convergence had been much faster than over 1996–97. However, it has to be acknowledged that all aggregative and quantitative studies are hampered by the short time period since unification and by the unreliability of some of the data. In particular, measured quantities of labour and especially capital in the East on unification may not reflect utilizable quantities.

Convergence of productivity per worker hour and convergence of output per capita are not the same thing. They are reasonably comparable if the age structures of the two regions are similar, participation rates by age and gender are within similar ranges and hours are similar. There was a large drop in the level of employment in the East soon after unification, with a significant rise in

3. From these data we cannot infer whether jobs have been destroyed or created as a result. However, if investment abroad has created jobs in Germany, it is likely that these were high-productive jobs such as those in R&D. Evidence in Barrell and Holland (1999) suggests much of this investment is market not export oriented and hence will not cause job losses in Germany.

early retirements, as can be seen from Figure 2. As can be seen from Figure 3 there was also an initial rise in hours per worker (as part-time workers withdrew) followed by a fall, albeit to above West German levels. These developments inevitably put a wedge between changes in productivity per hour or per worker and output per capita. In addition, in order for per worker and per capita figures to be comparable unemployment rates should also be of around the same magnitude, and they were not. Productivity may catch up because of significant labour shedding, accompanied by high measured unemployment and significant hidden unemployment, and this was clearly the case in the East.

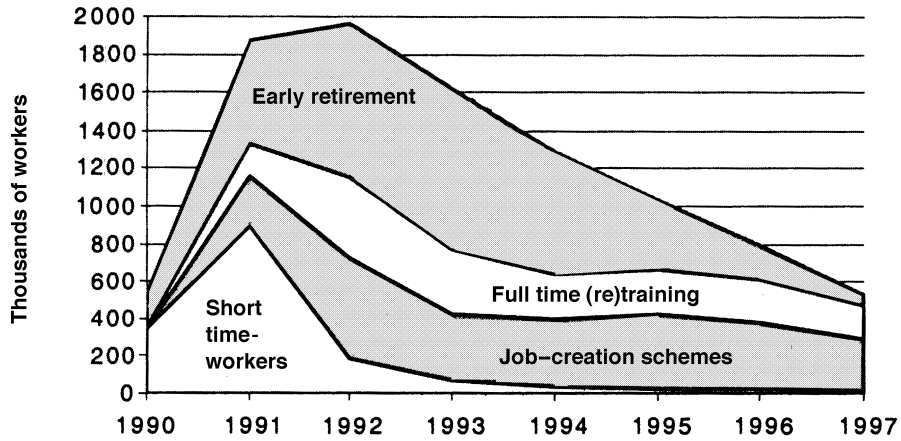

Figure 2 Cumulative effects of labour market measures in East Germany
Source: IAB (1998).

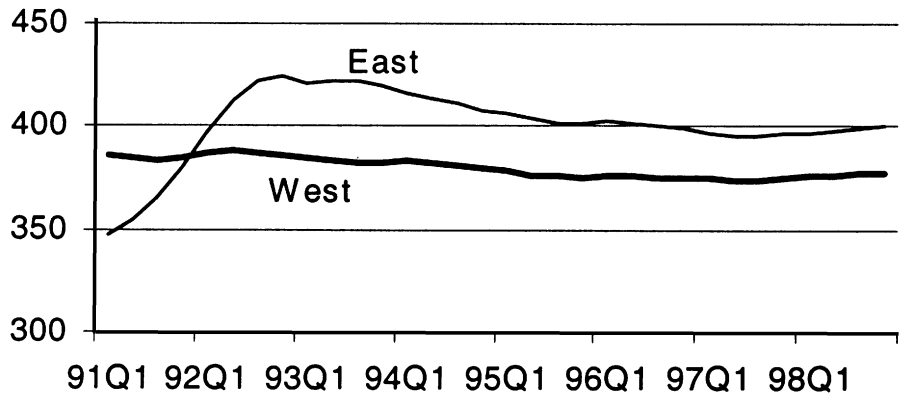

Figure 3 Hours worked per worker per quarter, 1991–98
Source: IAB (1998).

4. MODELLING CONVERGENCE OF LABOUR PRODUCTIVITY

Productivity studies usually assume that capital and labour produce an output mediated through a production function. There are a number of approaches in use, and a number of issues to take into account. The most common approach to convergence is to utilize a growth accounting framework, with Cobb–Douglas technology (unit elasticity of substitution) assumed to be in place. Barro and Sala-i-Martin (1991) are a good example of this approach, which has been widely used. We may write the Cobb–Douglas function as

$$Y = \alpha e^{techp} K^{\beta} L^{(1-\beta)} \tag{1}$$

where Y is output, K is capital and L is labour. We may take logs and changes, write the logs in lowercase and re-arrange to give the normal expression for the change in total factor productivity:

$$\Delta techp = \Delta y - \beta\, \Delta k - (1 - \beta)\Delta l \tag{2}$$

This framework for defining the 'Solow residual' allows us to go on and identify the sources of technical progress. Labour productivity growth is the result of increases in capital per unit of labour and of technical progress, as can be seen from (3):

$$\Delta y - \Delta l = \Delta techp + \beta(\Delta k - \Delta l) \tag{3}$$

Equation (3) makes it clear that we can distinguish between the determinants of overall productivity growth (total factor productivity growth) and the determinants of labour productivity growth in this context. However, studying labour productivity growth $(\Delta y - \Delta l)$ in this way requires good estimates of capital and labour inputs, and we need to assume that technical progress is neutral. This framework is only fully appropriate when the elasticity of substitution is one. The evidence, surveyed for instance in Rowthorn (1995), is that the elasticity of substitution is closer to a half, and we would argue that this is important when catching-up is being studied. Rodrik (1997) undertakes a study of the sources of growth for East Asia using Cobb–Douglas and CES technologies, and he is able to demonstrate that there are significant biases involved when using Cobb–Douglas functions when the world is CES with an elasticity in the range we suggest.

If the world is not Cobb–Douglas then total factor productivity growth cannot be written as a simple Solow residual. It is possible to undertake growth accounting in a CES framework, and Hubert and Pain (1999) do this for the UK. We choose not to follow this route because once again it requires that we have reliable and consistent data on the capital stock, and it is not clear to us that the measured value of capital in the East on unification bears any relation to its productive potential. Hence we have to find ways to look at the sources of the technical progress component of labour productivity growth without relying on estimates of the capital stock. There are two ways in which productivity can be increased: either give labour more capital to use, and hence allow for

convergence by capital deepening, or increase the efficiency with which labour operates. It is the second of these that we address.

We have chosen to start with a CES production function that embodies both neutral, capital- and labour-augmenting technological progress.[4] If the sources of technical progress are all exogenous then it is only possible to identify two of these, which can be described as neutral technical progress and the factor bias. However, as Barrell and Pain (1999) show, endogenous technical progress changes this. The CES production function, with constant returns to scale, can be written as follows:

$$Y = \gamma(e^{techn})[\delta(K(e^{techk}))^{-\rho} + (1+\delta)(Le^{techl})^{-\rho}]^{-1/\rho} \tag{4}$$

where Y is gross domestic output, K is the real capital stock and L is the labour input expressed as total hours worked (see Appendix). We have identified *techn* for neutral technical progress, *techk* for capital-augmenting technical progress and *techl* for labour-augmenting technical progress. Barrell and Pain (1999) estimate a production function for West Germany up to 1994 using the marginal productivity conditions for labour and for capital, and they estimate these relationships simultaneously. They find that labour-augmenting technical progress (improvements in education, perhaps) is exogenous and that the stock of foreign investment in West Germany (17 per cent of manufacturing employees in West Germany in 1990 were in foreign-owned plants) was a source of neutral technical progress. There was also some evidence that research and development efforts drove capital-augmenting technical progress.

It is straightforward to derive labour demand as a function of real wages, technical progress and output (see Barrell and Pain, 1997). The mark-up adjusted real wage ($M^*(w/p)$) can be set equal to the marginal product of labour derived from the production function, and it can then be rearranged to give a labour demand curve conditioned on output, the real wage and technical progress.[5]

The marginal product may be written as

$$\delta Y/\delta L = (\gamma(e^{techn}))^{-\rho}(1-\delta)Y^{(1+\rho)}(Le^{techl})^{-(1+\rho)}e^{techl} \tag{5}$$

And this may be used in the derivation of the log-labour demand function, where $\sigma = (1/(1-\rho))$ is the elasticity of substitution

$$\ln(L) = a + \ln(Y) - \sigma\ln(w/p) + (\sigma - 1)techp \tag{6}$$

4. The Cobb–Douglas production structure imposes a unit elasticity of substitution between labour and capital and embodies only neutral technological progress. The Translog production function, which is widely used, either needs an estimate of the stock of capital or its user cost (if we use the dual cost function), and has a tendency to collapse to unit elasticity of substitution production functions because of its innate structure. We wish to avoid these problems.
5. Even if technical progress is exogenous that does not necessarily imply that the technology trend is constant over the whole period.

Technological progress enters through the last term of equation (6), and it is driven by forces that can be neutral or have a factor bias. We could estimate equation (6) for West German data before unification and Germany after unification, and in the next section we do this in a dynamic context. This requires that on unification we add two labour demands together.[6] If we assume units of output and hours of labour are measured correctly and that real wages are also measured correctly we may write the aggregate version of (6) using only aggregates of these variables. However, the aggregate equation will have an intercept that is the weighted average of the two intercepts. Alternatively we could start with the assumption that the labour demand curves were different in the two economies, and estimate an unbalanced panel (with a long run of West German data and a short run of East German data) and test for similarities. We turn to this in the two subsequent sections of the paper.

The addition of the two labour demand functions also means that the two *techp* relationships are aggregated. Our presumption in this paper is that additional, different, factors affect technical progress in the East as compared to the West and the aggregate *techp* must reflect this. In particular, factors that cause the subsequent convergence of East German productivity levels on West German levels should be included in the aggregate. Hence, the level of technical progress can be written as

$$(\sigma - 1)techp = (\sigma - 1)techpw + (\sigma - 1)((techpe) + \varphi) \tag{7}$$

where *techp* is the level of technology, *techpw* represents the factors affecting technical progress in the West, φ is the drop in average technical progress on unification and *techpe* represents the set of factors that cause catch-up between East and West. One simple specification with exogenous catch-up might be

$$\ln(L) = a + \ln(Y) - \sigma \ln(w/p) + (\sigma - 1)\{techpw - 0.156/(1 + \xi unitime(-n))\} \tag{8}$$

where *unitime* represents a time trend starting after unification (1991). Our estimate of the aggregate fall in productivity is 15.6 per cent, and this is the level we use as the start of our 'shrinking' process with n equal to 4. We can write the technical progress function for Germany as a whole (*techp*) as

$$(\sigma - 1)techp = (\sigma - 1)techpw - (\sigma - 1)\{0.156/(1 + \xi unitime(-n))\} \tag{9}$$

and hence in the longer term both countries would have the same rate of growth of technical progress, and levels of technological progress are only temporarily different due to catching-up. The rate of convergence depends

6. Output per person-hour was significantly lower in the East, and hence the aggregate intercept has to reflect this. Average productivity in new Germany fell 14 per cent on unification. However, differences in productivity levels in a CES framework are due to both different levels of technology and different positions on the production possibility frontier. If wage differentials between East and West were not the same as underlying productivity differences, then the observed differential will include a wage-driven offset (if wages are too high). Given observed differences and an elasticity of substitution of a half we can gauge that the aggregate technical progress function fell by 15.6 per cent.

upon the parameter ξ. If ξ were 0.1 then 10 per cent of the shortfall would disappear in the first period. The time trend *unitime* is lagged enough to ensure that average technical progress falls by 15.6 per cent in the first year and then shrinks geometrically thereafter. Once *unitime* is large the catching-up of Eastern labour productivity to Western levels is nearly complete. The rate of decline in the gap is geometric in this case, but it could be slow in the early stages, but it is more rapid in equation (9′) where we introduce an exponent on the unification trend-like dummy.[7]

$$(\sigma - 1)techp = (\sigma - 1)techpw - (\sigma - 1)\{0.156/(1 + \xi unitime^2(-n))\} \qquad (9')$$

Our long-run labour demand curve (8) using (9) or (9′)[8] can be embedded in the dynamic error correction form. We should not assume we could estimate this by OLS. Endogeneity may occur because the current changes in GDP (Y) and in the real wage (w/p) are not fully exogenous for labour demand (E). Hence, we have to use instruments in the estimation of the dynamic form of equation (8). In general, lags of the right-hand-side variables that need instrumenting provide valid instruments. We include Sargan's test for the validity of instruments.

We estimate a dynamic form of equation (8) over the period 1975Q1–1997Q4, which includes a major structural break. We choose to use whole economy output, as the transformation of the process of producing national income affected all sectors. We also use total employment in hours in the economy, so our productivity measure covers total output per person-hour. In order to index real wages we use total compensation per person-hour for employees in employment deflated by the GDP deflator at factor cost (to exclude indirect taxes etc.). In addition, we need to be careful in assessing the growth of labour productivity in 1996–97. We have discussed above the reasons why productivity growth in 1997 was high and econometric analysis by the OECD (1998, pp. 27–29) shows that the decline in business sector employment has been much greater than could have been expected on the basis of past behaviour.

7. We could have undertaken a grid search for the most appropriate exponent, but the data period is relatively short and we did not feel that this result would have been robust.
8. Note that for (9)

$$\frac{\partial \eta t}{\partial unitime} = -0.156(1 + \xi unitime)^{-2}\xi$$

whilst for (9′)

$$\frac{\partial \eta t}{\partial unitime} = -0.156(1 + \xi unitime^2)^{-2}\xi * 2 * unitime$$

and hence time dependence differs between the two specifications. Suppose we estimate $\xi = 0.04$ in (9) and $\xi = 0.002$ in (9′); see Table 5. Then the derivative with respect to *unitime* in (9′) will be larger than in (9) for the first ten periods. However, the level of the productivity gap using (9′) and the estimated parameters will be smaller than in (9) in the first 20 periods.

We present estimation results in Table 5. All parameters are significant, and all diagnostic tests are passed. The elasticity of substitution has been estimated to be below 0.5 and hence deviates significantly from Cobb–Douglas where it would be unity. The coefficient on the long-run parameter for productivity growth indicates it has been 0.6 per cent per quarter, or about 2.5 per cent per annum, which is relatively high by the standards of the late 1980s but is representative of West Germany over our whole data period. We estimate both a geometric and an accelerated geometric convergence process and both specifications suggest positive and significant catch-up parameters. However, the two specifications have different implications for the period of catching-up.

The quadratic specification (*unidum*^{2}) would imply that full catching-up and convergence has almost been achieved in 2030. The linear specification (*unidum*) implies that productivity by then is still around 2 per cent below the

Table 5 Exogenous catching-up

$$\begin{aligned}\Delta \ln(L) = {} & \lambda\{\ln(L_{t-1}) - \ln(Y_{t-1}) + \sigma \ln(w/p)_{t-1} \\ & - (\sigma - 1)\{techpw - 0.156/(1 + \xi unitime^{\varphi}(-n))\}\} \\ & + \theta_1 \Delta \ln(Y_t) + \theta_2 \Delta \ln(w/p)_t + \theta_3 \Delta \ln(w/p)_{t-1} + cons + \varepsilon_t\end{aligned}$$

	Equation (8) using (9) (linear time)		Equation (8) using (9′) (squared time)	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
λ	−0.37	(−5.87)	−0.39	(−6.06)
σ	0.38	(4.04)	0.43	(5.64)
Techpw	0.0064	(20.5)	0.0066	(25.3)
ξ	0.0416	(2.33)	0.00206	(2.37)
θ_1	0.565	(6.32)	0.56	(6.29)
θ_2	−1.13	(−13.4)	−1.15	(−14.0)
θ_3	−0.16	(−3.11)	−0.17	(−3.32)
D841842	0.025	(3.98)	0.025	(3.07)
Constant	1.73	(3.30)	1.53	(3.33)
Diagnostics				
R-bar	0.92		0.92	
SE	0.7822%		0.7740%	
Ser Cor 4	7.12		8.03	
Norm	0.64		0.14	
Het	0.16		0.22	
Sargan	14.2		10.8	

Notes: Non-linear IV estimation with constraint imposed to recover the elasticity of substitution, σ, 75Q1–97Q4, *t*-values between parentheses. Instruments: all variables except current changes, plus change in EU GDP, change in EU GDP lagged, change in GDP double-lagged, change in real wages lagged, change in real wages double-lagged, D91. Tests are described in Pesaran and Pesaran (1997), *Mfit* manual.

pre-unification trend and hence East German labour productivity would be about 10 per cent lower than that in West Germany. Our linear specification implies that the initial gap has narrowed by 15 per cent after one year. This is equivalent to saying that East German productivity has converged by 7.5 per cent to West German levels after a full year. It is difficult to distinguish between linear and quadratic catching-up specifications on the basis of specification tests and standard errors. The quadratic form has the lower standard error, and hence may be the better explanation. However, we have to accept that the assumption that there is one production function for Germany before and after unification may affect our results. We turn to this issue in the next two sections.

5. ENDOGENOUS CATCHING-UP

Differences in levels of productivity depend on organization gaps, idea gaps and object gaps.[9] Convergence implies that these gaps are closed, and this will be largely due to the effects of economic activities such as those described in Table 6. The closing of the organization gap implies the movement of firms towards their production possibilities frontier and hence implies a reduction of *X*-inefficiency. The closing of the idea gap is the transferring of technological know-how, while the closing of the object gap involves acquiring the necessary equipment and capital.

We wish to look for the factors affecting technical progress in each of East and West Germany in this section. In order that we can do that we utilize (unbalanced) panel data analysis with fixed effects that imply that the steady-state level of productivity can differ between East and West Germany. Equation (10) repeats our labour demand curve, with subscript *i* representing East or

Table 6 Sources of catching-up in East German industry

	1991	1992	1993	1994	1995	1996	1997/98
% employees in private firms	8	41	76[a]	76[a]	95	95	99[b]
% employees in 'foreign'-owned firms	7	23	34[a]	34[a]	45	44	50[b]
% foreign-owned firms	5	17	14[a]	14[a]	22	22	23[b]

Notes:
[a] Data refer to winter 1993/94.
[b] Data refer to the beginning of 1998.
Source: DIW (1999).

9. Romer (1993) distinguishes between ideas and object gaps. We add organization gaps as we think they are particularly important in the East German case. See also Dornbusch and Wolf (1992).

West Germany and subscript t representing time. The unbalanced panel contains no data for East Germany before 1991. The technical progress term, $techp_i$ depends upon exogenous time trends and on any factors that vary over time that we think impinge directly on the rate of absorption of new technologies. In particular we look for effects from the privatization progress and from the import of knowledge from West Germany through West German control of firms in the East.

$$\ln(L_{it}) = a_i + \ln(Y_{it}) - \sigma_i \ln(w_{it}/p_{it}) + (\sigma_i - 1)techp_{ti} \tag{10}$$

The Treuhandanstalt privatized about 20,000 firms in the four years after unification (DIW, 1999). This has transformed East Germany from a socially planned economy into a market economy. The Treuhand restructured firms and broke up the large firms (VEBs) that used to dominate East Germany into single-plant firms that were easier to sell, and left new owners to undertake further restructuring. This organizational change within firms reduced the *X*-inefficiency that was so prevalent in the East. East German industry now consists almost entirely of private firms.

The transfer of technological know-how should not have been difficult given the close relation between East Germans and West Germans in terms of language and culture. Indeed, there has been a rapid increase in the percentage of total employees in the East German industry employed by 'foreign'-owned firms, where foreign includes West German firms. Half of the employees were employed in foreign firms in 1997, while this was only 7 per cent in 1991. These firms have brought with them new and more efficient ways of production. As DIW (1998) shows, there are benefits from the presence of 'foreign' firms. Foreign firms are more likely to export, they invest more per employee and their capital stock, both equipment and structures, is thought to be more up to date than that of indigenous firms.

Carlin and Mayer (1995) argue that the Treuhand was operated in a way that ensured that West German firms now dominate the control and ownership of East German firms. This control has been used to secure access to West German finance, wider markets than those in the Eastern Länder, and management techniques common in the West. Indeed, most investment in East Germany has come via 'foreign' firms and in the form of subsidized investment. Little has been financed directly by banks, although this is the common pattern in the West. Investment per employee in East German industry in 'foreign' firms was 60 per cent higher than in indigenous firms by 1997. Completion of the restructuring process seems to be fastest when control is in the hands of 'foreign' firms.[10]

The conditions to close the organizational, idea and object gaps have all been favourable for East Germany and we test whether the percentage of East German industrial employees in private firms (*PRIV*) and in 'foreign' firms

10. The literature on transition distinguishes between reactive, cost-oriented restructuring and deep and strategic restructuring. Private firms, and 'foreign' firms in East Germany, are more likely to deliver strategic restructuring.

(*FOR*) explain convergence. The Appendix explains how we collected data on all the parts of the equation. We have data for total output in each of the countries, we have data on employment, on hours and on compensation. We construct a measure of the wage (or compensation) per person-hour and use this to explain the level of employment.[11] Hence, for each economy we can use whole economy output and employment and compensation per person-hour deflated by the GDP deflator at factor cost.

We have sufficient data to undertake an unbalanced dynamic panel regression with fixed effects and hence different steady states in East and West. We can check if the dynamics of adjustment are the same by including a lagged dependent variable in the regression for each country and testing to see if they are significantly different. We can also test to see if the elasticity of substitution is the same in the East and the West after we have allowed for differences in the factors affecting technical progress. We allow exogenous technical progress to be different in each of the countries, and we include country-specific endogenous factors where available and appropriate.

If we had a large amount of data we could have used an encompassing framework where both the technology transferring variables and an exogenous time trend were present. However, we have only a limited amount of data, and we have to use a different strategy, and we have had to exclude explicit determinants of technical progress in West Germany. We undertook analyses with each of the variables in turn and we make some preliminary comments on their relative importance.

Table 7 presents the estimation results, and we start with a model (I) where East and West Germany are allowed to be different within the framework of a long-run constant returns to scale CES production function. We make our general model more parsimonious using *FOR*, the West German ownership variable as well as different exogenous time trend-related technical progress variables in East and West Germany. Exogenous technical progress (absorption of ideas perhaps) is much faster in the East than the West, and we do not test for the equality of these two coefficients. There is no difference between the lagged dependent variables in the two parts of the panel, and hence we can drop the additional lag effect for the East. In regression (II) we find that there is no significant difference between the elasticities of substitution and hence we can drop the term reflecting differences between East and West as well.

East and West Germany have a common lag structure and a common elasticity of substitution, but they have different intercepts, and technical progress is faster in the East. This is in part because of faster exogenous technical progress, but also because the catch-up variable only applies to the East. The rate of technical progress is endogenous, but it will have slowed down markedly in the East as the privatization process has been completed and the transfer of employees to West German firms has slowed. The table reports in

11. We follow common practice and assume that the average wage for all in employment is the same as for employees in employment. This assumption is relaxed in the next section.

Table 7 An unbalanced labour demand panel of East and West Germany

Whole economy

$$\ln\left(\frac{L_{it}}{Y_{it}}\right) = \alpha_i + \lambda_{WG\&EG}\ln(L_{i,t-1}) + \theta_{1,EG\&WG}\ln(w/p)_{it} + \theta_{2,i}t_i + \lambda_{EG}\ln(L_{EG,t-1}) + \theta_{1,EG}\ln(w/p)_{EGt} + \theta_{3,EG}CATCH\text{-}UP + \varepsilon_{it} \quad i = WG,\ EG$$

	(I) *FOR*	(II) *FOR*	(III) *FOR*	(IV) *PRIV*
$\lambda_{WG\&EG}$	0.13 (2.9)	0.12 (2.4)	0.14 (2.9)	0.18 (3.9)
$\theta_{1,EG\&WG}$	−0.36 (−2.0)	−0.39 (−2.6)	−0.56 (−14.6)	−0.54 (−14.3)
$\theta_{2,WG}$	−0.0031 (−15.4)	−0.0031 (−15.3)	−0.0032 (−15.9)	−0.0032 (−16.4)
$\theta_{2,EG}$	−0.0071 (−1.7)	−0.0060 (−3.0)	−0.0057 (−8.1)	−0.0057 (−8.1)
λ_{EG}	−0.13 (−0.36)			
$\theta_{1,EG}$	−0.21 (−1.15)	−0.18 (−1.18)		
θ_3	−0.48 (−3.5)	−0.50 (−5.7)	−0.52 (−5.9)	−0.20 (−7.9)
α_{WG}	−0.42	−0.32	−0.37	−0.74
α_{EG}	5.39	3.11	0.26	−0.06
Standard error of regression	0.0155	0.0154	0.0155	0.0142
Sample	70Q2–98Q4; 91Q3–98Q4	70Q2–98Q4; 91Q3–98Q4	70Q2–98Q4; 91Q3–98Q4	70Q2–98Q4; 91Q3–98Q4
Long run[a]				
Elasticity of substitution			0.65 (17.0)	0.66 (16.4)
Labour-augmenting technical progress *WG*			0.010 (8.2)	0.011 (7.9)
Labour-augmenting technical progress *EG*			0.014 (3.3)	0.020 (6.8)
Catch-up variable			1.71 (4.3)	0.70 (5.0)

Notes: *t*-Statistics in parentheses are heteroscedastic-consistent (using TSP43).
CATCH-UP: *PRIV* = % of East German employees in private firms, industry
FOR = % of East German employees in 'foreign' firms, industry

[a] subst $= \dfrac{\theta_{1,EG\&WG}}{\lambda_{EG\&WG} - 1}$ tech $WG = \dfrac{\theta_{2,WG}}{\lambda_{EG\&WG} - 1 - \theta_{1,EG\&WG}}$ tech $EG = \dfrac{\theta_{2,EG}}{\lambda_{EG\&WG} - 1 - \theta_{1,EG\&WG}}$

standard errors derived by delta method (see e.g. Pesaran and Pesaran, 1997).

(IV) on the use of the privatization indicator. As can be seen, the overall elasticity of substitution is around 0.65 whichever technical progress indicator is used. These estimates are markedly higher than when we assume we have one aggregate production function. If we use foreign ownership as an indicator variable, then exogenous technical progress is 40 per cent higher in the long run in the East than in the West. If we use privatization, then exogenous technical progress in the East is almost double that in the West.

In specification *PRIV*, an increase of 100 percentage points in the percentage of employees in private firms in the industrial sector in the East increases productivity by 70 per cent as compared to its initial level in the *first quarter of 1991*. This process, would, however, be continuing beyond the end of our sample as the equation contains a lagged dependent variable. This is similar to closing the organizational gap. In specification *FOR*, an increase of 50 percentage points in the percentage of employees in 'foreign' firms would increase productivity in the East by 80 per cent of its initial level in the *first quarter of 1991*. This is similar to closing the ideas gap.

We also tested whether two other variables discussed above help us explain productivity changes in either the East or the West. However, a variable describing labour shedding (number of people on labour market measures, see Figure 2) proved insignificant in East Germany, whilst a variable measuring the number of employees in East European countries under the control of foreign-owned firms (see Table 4) proved insignificant in the regression for West Germany. However, both were of the correct sign, but we excluded them on grounds of parsimony.

We conclude that solving the ideas gap is important in removing the productivity differences between East and West Germany. Closing the organizational and object gaps also plays a significant role in East Germany. One needs to bear in mind that 'foreign' firms are usually private firms and therefore these two explanations are not mutually exclusive. To the extent that they bring additional capital to East Germany, they will also be able to close the object gap. It is of course difficult to choose between these specifications, and on the basis of the standard error of the equations we might prefer the use of privatization as a measure. We would advise against making a choice given the limited amount of data and the fact that these explanations are very similar. 'Foreign' firms drove the privatization of large Eastern firms, and they invested in new capital, and object, ideas and organizational gaps were closed as a result. There may also be a role for exogenous catch-up as new ideas are absorbed by the working population from their new environment, and in the longer term it would be useful to model this further.

6. CATCHING-UP IN INDUSTRY

In this section we discuss convergence at a more disaggregated level. Figure 4 shows convergence of productivity as measured by output per employee for five

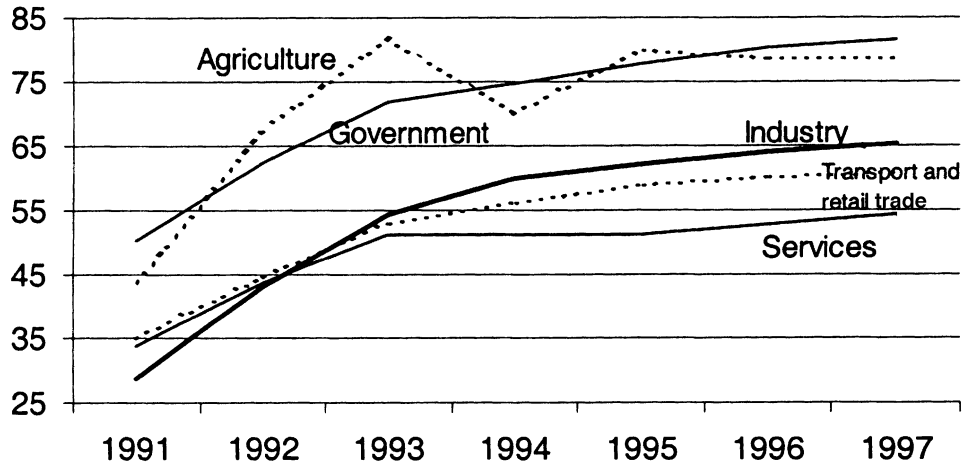

Figure 4 Output per employee (East/West)

Source: DIW (1999).

different sectors: agriculture, government, industry, transport, and retail trades and services. In what follows we will first of all look at β-convergence (see Barro and Sala-i-Martin, 1991, for a definition) amongst sectors over time, and then we will look at the determinants of manufacturing productivity before turning to a sectoral analysis of some of the factors that might influence the speed at which convergence takes place.

Table 8 contains annual rates of convergence of labour productivity consistent with the data in Figure 4. Convergence rates show how much of the productivity gap between East and West is closed each year. They can be compared to the conventional β-convergence rates in Barro and Sala-i-Martin (1991). We assume that East German productivity converges on the average West German level, although following Funke and Strulik (1999), we do not

Table 8 Annual rates of labour productivity convergence

	1992	1993	1994	1995	1996	1997	1992–97
Agriculture	42	44	−65	34	−6	0	8.44
Industry	20	20	12	5	5	3	7.14
Of which: Manufacturing	15	17	13	9	6	11	7.36
Retail trade and transport	15	15	6	7	3	2	5.76
Services	15	13	0	0	3	3	4.58
Government	24	25	10	13	10	7	8.45
Total[a] excl. agr. and govt	13.6	12.8	5.1	2.7	3.2	2.3	6.51

Note:
[a] Weighted average, with weights 0.438 (*IND*), 0.168 (*RET*) and 0.394 (*SERV*).
Sources: DIW (1999), IWH (1999) and own calculations.

necessarily see this as the only possibility, but it is a useful benchmark for this simple descriptive statistic. However, we need to bear in mind that effects such as different business cycles inevitably cause problems in the estimation of the true rate of convergence in one-year or short time period analyses. Nevertheless, as can be seen from Figure 4, there seems to be a deceleration of convergence over the years. We were able to capture this deceleration in the previous section by the inclusion of catching-up variables, and we can do the same for the industry sector in this section of the paper. The pattern that emerges from Table 8 is affected by the surge in construction investment immediately after unification and by the government sector where productivity measures reflect pay rather than output. A smoother path can be seen for the manufacturing sector, with strong rates of convergence over 1992–97.

Productivity 'convergence' in industry was particularly fast, as can be seen from Figure 5, which plots output per person-hour for both the East and the West over the period 1991–98. We repeat our unbalanced panel analysis in Table 9, and we now apply it to data for industrial employment and output in East and West Germany separately. We use output per employee-hour as the dependent variable and we use compensation per employee-hour deflated by the factor cost GDP deflator. Almost all output in industry is produced by employees, and hence we do not need to concern ourselves about assumptions that cover the difference between employment and employees in employment as we had to above.

We again start with a general model with foreign ownership as our endogenous growth factor, and we test in Table 9 to see if we can drop the additional lag effect in East Germany from specification (V). We can, and in specification (VI) we can also drop the additional elasticity of substitution effect in East Germany, and hence we can claim that there are commonalities in the equations. However, the intercepts differ, and the technical progress

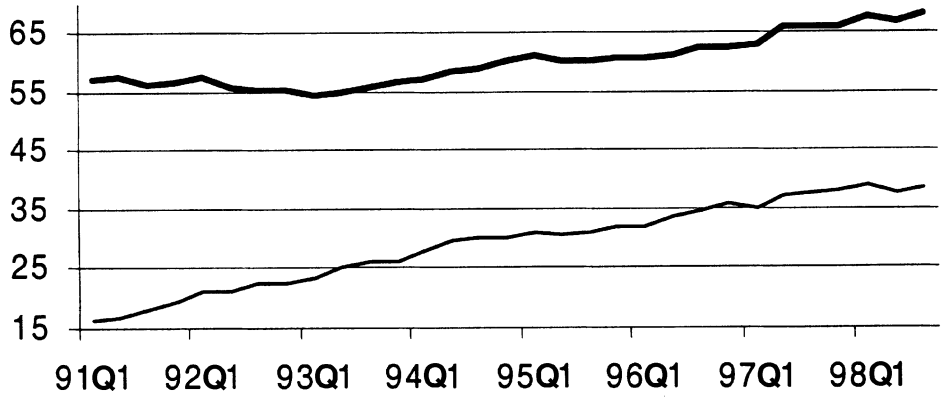

Figure 5 Production per hour in industry East and West Germany, 1991–98, in DM (1991 prices)

Table 9 An unbalanced labour demand panel of East and West Germany

Producing industries

$$\ln\left(\frac{L_{it}}{Y_{it}}\right) = \alpha_i + \lambda_{WG\&EG} \ln(L_{i,t-1}) + \theta_{1,EG\&WG} \ln(w/p)_{it} + \theta_{2,t} t_i + \lambda_{EG} \ln(L_{EG,t-1}) + \theta_{1,EG} \ln(w/p)_{EGt} + \theta_{3,EG} CATCH\text{-}UP + \varepsilon_{it} \quad i = WG,\ EG$$

	(V) *FOR*	(VI) *FOR*	(VII) *FOR*	(VIII) *PRIV*
$\lambda_{WG\&EG}$	0.20 (2.9)	0.21 (3.5)	0.21 (3.4)	0.23 (3.8)
$\theta_{1,EG\&WG}$	−0.49 (−2.7)	−0.47 (−2.6)	−0.50 (−12.1)	−0.49 (−11.8)
$\theta_{2,WG}$	−0.0016 (−4.0)	−0.0016 (−4.0)	−0.0016 (−4.1)	−0.0016 (−4.2)
$\theta_{2,EG}$	−0.0052 (−2.0)	−0.0056 (−2.2)	−0.0052 (−3.1)	−0.0082 (−7.9)
λ_{EG}	0.10 (0.5)			
$\theta_{1,EG}$	−0.012 (0.06)	−0.033 (−0.18)		
θ_3	−0.83 (−4.9)	−0.89 (−6.8)	−0.88 (−7.6)	−0.31 (−9.2)
α_{WG}	1.85	1.69	1.68	1.56
α_{EG}	1.55	3.03	2.67	2.53
Standard error of regression	0.02836	0.02829	0.02819	0.02689
Sample	68Q2–98Q4; 91Q2–98Q4	68Q2–98Q4; 91Q2–98Q4	68Q2–98Q4; 91Q2–98Q4	68Q2–98Q4; 91Q2–98Q4
Long run				
Elasticity of substitution			0.63 (10.5)	0.64 (10.7)
Labour-augmenting technical progress *WG*			0.006 (10.0)	0.006 (10.0)
Labour-augmenting technical progress *EG*			0.018 (2.6)	0.029 (4.8)
Catch-up variable			3.05 (4.6)	1.12 (4.7)

Note: See Table 8 on whole economy results.

terms also differ, and hence the implied steady states differ. The elasticity of substitution is around 0.6 and it is significantly different from zero and from one. Labour augmenting and/or neutral technical progress in industry in West Germany runs at about 2.5 per cent a year. This is not the same rate as the growth of labour productivity as this depends on the accumulation of capital as well as on the rate of technical progress.

Exogenous technical progress appears to be running at three times this rate in the East if we use *FOR* as the endogenous growth factor. The coefficient on *FOR* or 3.05, which means that initial productivity will eventually rise by 135 per cent as a result of the change in ownership and organization. In combination with the rate of exogenous technical progress over seven years this suggests that technical progress alone should raise the productivity of labour by about 180 per cent. The actual increase from 15 to 40 DM per person-hour in 1991 prices is around this size, suggesting productivity growth will continue to exceed levels in the West for some time, as the observed increase also includes the effects of increased capital per employee which will also have raised measured productivity. If we use the level of privatization as an endogenous technology transfer variable, then slightly more of the improvement in productivity is explained by exogenous technical progress.

Again, we tested whether the two other variables discussed above explain productivity changes in either the East or the West. In addition, we attempted to use a variable describing labour shedding (number of people on labour market measures, see Figure 2) but it proved insignificant in East Germany. A variable measuring the number of employees in East European countries under control of foreign-owned firms (see Table 4) also proved to be insignificant in the regression for West Germany. They were of the correct sign, but were omitted for reasons of parsimony.

7. CONCLUSIONS

This paper addressed convergence of labour productivity in East Germany towards West German levels. The sudden formation of GEMU was followed by large transfers to East Germany, migration of workers to West Germany and reorganization and privatization of East German firms. This has led to a rapid closing of the organizational, ideas and object gap that existed between East and West Germany. We have shown that equations embedding both exogenous and endogenous technical progress are able to explain some of the convergence of labour productivity levels. It appears that the emergence of foreign and West German firms has helped to speed up the convergence process in East Germany. However, the convergence process slowed in the late 1990s as privatizations were completed, and a significant gap still exists between the East and the West in terms of productivity per person-hour. Organizational change may have done as much as is possible, and the problem of further convergence may be embedded in the stock of human capital, with

increases in education spending being perhaps more important than further capital deepening. It is only in this way that the stock of knowledge and the organizational structure of the economy will continue to improve.

APPENDIX: DATA SOURCES

All data are according to ESA79, and in logs. Data from the Bundesbank were seasonally adjusted, and other data with seasonal patterns have been seasonally adjusted by the X-11 procedure.

Whole economy

L	Total hours worked ($E * HOURS$).
w/p	Real average compensation per employee-hour ($COMP/(EE * HOURS * PY)$).

Whole Germany, whole economy

E	Total employment, (West Germany before 1991), Bundesbank/ OECD.
EE	Employees in employment, (West Germany before 1991), Bundesbank.
Y	Gross domestic product, (West Germany before 1991), Bundesbank.
PY	GDP deflator (Bundesbank) adjusted for indirect taxes (Bundesbank).
COMP	Wages and salaries of employees in employment, (West Germany before 1991), Bundesbank.
HOURS	Hours worked per employee quarter, (West Germany before 1991), OECD employment outlook.

West Germany, whole economy after 1991

E	Total employment, Bundesbank.
EE	Employees in employment, Bundesbank.
Y	Gross domestic product, Bundesbank.
PY	GDP deflator (Bundesbank) adjusted for indirect taxes (Bundesbank).
COMP	Wages and salaries of employees in employment, Bundesbank.
HOURS	Hours worked per employee quarter, IAB.

East Germany, whole economy after 1991

E	Total employment, Bundesbank/OECD.
EE	Employees in employment, Bundesbank.
Y	Gross domestic product, Bundesbank.
PY	GDP deflator (Bundesbank) adjusted for indirect taxes (Bundesbank).
COMP	Wages and salaries of employees in employment, Bundesbank.
HOURS	Hours worked per employee quarter, IAB.

Industry

L Total hours worked ($E * HOURS$).
w/p Real average compensation per worker hour ($COMP/(E * HOURS * PY)$).

West Germany, industry (mining, manufacturing, construction and water and energy production)
E Total employment, OECD Quarterly Labour Force (before 1991) and Statistisches Bundesamt (after 1991).
Y Gross domestic product, OECD Quarterly National Accounts (before 1991), and Statistisches Bundesamt (after 1991).
PY Prior to 1991 defined as value over volume from OECD Quarterly National Accounts, and after 1991 from Statistisches Bundesamt, all adjusted for by whole economy indirect tax rates (Bundesbank).
COMP Prior to 1991 OECD Annual National Accounts: Wages and salaries of workers, annual data interpolated by whole economy *COMP*, and after 1991 from Statistisches Bundesamt.
HOURS See whole economy.

East Germany (after 1991), industry (mining, manufacturing, construction and water and energy production)
E Total employment, Statistisches Bundesamt.
Y Gross domestic product, Statistisches Bundesamt.
PY Defined as value over volume from Statistisches Bundesamt, adjusted for by whole economy indirect tax rates (Bundesbank).
COMP Wages and salaries of workers, from Statistisches Bundesamt.
HOURS See whole economy.

REFERENCES

Aghion, P., O. J. Blanchard and W. Carlin (1994), 'The Economics of Enterprise Restructuring in Central and Eastern Europe', CEPR Discussion Paper No. 1058.
Akerlof, G., A. K. Rose, J. L. Yellen and H. Hassenius (1991), 'East Germany in from the Cold: The Economic Aftermath of Currency Union', *Brookings Papers on Economic Activity* 1, 1–105.
Barrell, R. and D. Holland (1999), 'Foreign Direct Investment in Central European Manufacturing: Consequences for Enterprise Restructuring and Labour Productivity', NIESR mimeo.
Barrell, R. and N. Pain (1997), 'Foreign Direct Investment, Technological Change, and Economic Growth within Europe', *Economic Journal* 107, 1770–1776.
Barrell, R. and N. Pain (1999), 'Foreign Direct Investment, Innovation and Economic Growth within Europe', in: C. Driver and P. Temple (eds.), *Investment, Growth and Employment: Perspectives for Policy*, Routledge, London, pp. 199–220.
Barro, R. J. and X. Sala-i-Martin (1991), 'Convergence across States and Regions',

Brookings Papers on Economic Activity 1, 107–182.
Bellman, L. and M. Brussig (1999) 'Productivity Differences between Western and Eastern German Establishments', *IAB Labour Market Topics* 37.
Boltho, A., W. Carlin and P. Scaramozzino (1996), 'Will East Germany become a New Mezzogiorno?', CEPR Discussion Paper No. 1256.
Bundesbank (1999), *Monthly Report*, May.
Burda, M. and M. Funke (1995), 'Eastern Germany: Can't we be more optimistic?', *IFO Studien*, pp. 327–354.
Carlin, W. and P. Richthofen (1994), 'The Financial System in the Transition: The Special Case of East Germany', UCL Discussion Paper No. 94-06.
Carlin, W. and C. Mayer (1995), 'Structure and Ownership of East German Enterprises', *Japanese and International Economies* 9(4), 426–453.
DIW (1998), 'Gesamtwirtschaftliche und unternehmerische Anpassungsfortschritte in Ostdeutschland. Achzehnter Bericht', *Wochenbericht* 33/98.
DIW (1999), 'Gesamtwirtschaftliche und unternehmerische Anpassungsfortschritte in Ostdeutschland', *Wochenbericht* 23/99.
Dornbusch, R. and H. Wolf (1992), 'Economic Transition in Eastern Germany', *Brookings Papers on Economic Activity* 1, 235–261.
Franz, W. and V. Steiner (2000) 'Wages in the East German Transition Process', mimeo, ZEW University of Mannheim, Paper presented at CESifo Conference on German Unification 10 Years After, Berlin, 9 and 10 November 1999.
Funke, M. and H. Strulik (1999) 'Regional Growth in West Germany: Convergence or Divergence?', *Economic Modelling* 16, 489–502.
Hubert, F. and N. Pain (1999), 'Inward Investment and Technical Progress in the UK', Paper presented at the European Econometric Society Meeting in Santiago de Compostella, September 1999.
Hughes Hallet, A. and Y. Ma (1993), 'East Germany, West Germany and their Mezzogiorno Problem: A Parable for European Economic Integration', *Economic Journal* 103, 416–428.
Hughes Hallet, A., Y. Ma and J. Melitz (1996), 'Unification and the Policy Predicament in Germany', *Economic Modelling*, 13, 519–544.
IAB (1998), 'Labour Market Trends and Active Labour Market Policy in the Eastern German Transformation Process 1990–1997', Research Memorandum.
IFO (1997), 'Trotz höheren Risiken: Aufschwung setzt sich fort', *IFO Wirtschaftskonjunktur* 12/1997.
IFO (1998), 'Weiter nachlassende Investitionstätigkeit in Ostdeutschland', *IFO Schnelldienst* 31/1998, 16–19.
IWH (1999), *Wirtschaft im Wandel*, various issues.
Keller, W. (1997), 'From Socialist Showcase to Mezzogiorno? Lesson on the Role of Technical Change from East Germany's Post-World War II Growth Performance', NBER Working Paper No. 6079.
Lee, K., M. H. Pesaran and R. P. Smith (1997), 'Growth and Convergence in a Multicountry Empirical Stochastic Solow Model', *Journal of Applied Econometrics* 12, 357–392.
Lindlar, L. and W. Scheremet (1998), 'Germany's Slump Explaining the Unemployment Crisis of the 1990s', DIW Discussion Paper No. 169.
OECD (1991), *OECD Economic Surveys: Germany*, OECD, Paris.
OECD (1998), *OECD Economic Surveys: Germany*, OECD, Paris.
Pesaran, M. H. and B. Pesaran (1997), *Microfit 4.0*, Oxford University Press, Oxford.

Rodrik, D. (1997) 'TFPG Controversies, Institutions and Economic Performance in East Asia', NBER Working Paper No. 5914.
Romer, D. (1996), *Advanced Macroeconomics*, McGraw-Hill, New York.
Romer, P. (1993), 'Idea Gaps and Object Gaps in Economic Development', *Journal of Monetary Economics* 32, 543–573.
Rowthorn, R. (1995), 'Capital Formation and Unemployment', *Oxford Review of Economic Policy* 11(1), 26–39.
Sinn, H. W. (1999), 'EU Enlargement, Migration, and Lessons from German Unification', CESifo Working Paper No. 182.

