Growth and Convergence in a Two-Region Model of Unified Germany

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Abstract. The paper sets up a two-region endogenous growth model to discuss growth and regional convergence of unified Germany. It emphasizes the role of private and public capital accumulation during the developing process. The theoretical part derives fiscal policy rules which establish convergence of regional output per capita and convergence of regional human wealth. To assess the speed of convergence the model is calibrated with German data. Given a fiscal policy rule that is consistent with the data on government spending in East and West Germany after unification the model suggests that East Germany will reach 80 per cent of West Germany's income per capita between 20 and 30 years after unification and that actual transfers are approximately sufficient to equalize regional human wealth. The results are compared with an extension of the model that includes wage-setting behaviour and unemployment in the eastern region.

1. INTRODUCTION

On 2 July 1990, East and West Germany became economically united through a common currency. Ten years after, the effects of German reunification continue to reverberate in Germany. The abrupt exposure of the structurally weak East German economy to competition from the world markets in 1990 resulted in a strong decline of economic activity in the five new federal states (Bundesländer). The industrial depression that followed the shock of unification ended in 1991 but on the other hand there is no Wirtschaftswunder. West Germany's postwar recovery was buttressed by an undervalued Deutschmark and by low wages, both of which boosted exports. Eastern Germany has neither advantage; instead it is suffering from two policy blunders. Unification saddled the region with a currency whose value reflected western Germany's highly productive industry. And employers worsened that handicap by agreeing to raise eastern German wages to western levels far more rapidly than the productivity gap could be closed. Given this situation both state governments and the Treuhandanstalt, the agency charged with privatizing eastern German
industry, have rescued ‘industrial cores’ on the theory that new businesses will spring up only where some industry still survives. But the price of such rescues has been very high. The resulting cost of regenerating eastern Germany turned out to be massive. Despite the more than 1,000 billion DM poured into the East since the Berlin Wall came down ten years ago, productivity there is only 60 per cent of West Germany’s; eastern unemployment, at 18 per cent, is double. As a result, parts of the eastern economy have become so addicted to subsidies that they may become a German version of Italy’s poor south, the Mezzogiorno. Over the same period Germany’s public debt has jumped twofold since 1990 to 1,500 billion DM. Given these developments, the paper deals with the long-term prospects of the East German economy. We consider the impact of fiscal policy in a two-region endogenous growth model which emphasizes the role of private and public capital accumulation during the transition process.

The theoretical model can be understood as an extension of Ono and Shibata’s (1992) two-country model with public capital accumulation and interregional fiscal transfers. Emphasizing the role of factor accumulation during the catching-up process, economic growth is driven by the accumulation of private and public capital. Therefore, the model can also be understood as a two-country (region) version of Barro’s (1990) model on government spending and economic growth. In contrast to Barro (1990), however, we will regard productive government expenditure as a flow variable that extends the stock of available public capital. Therefore, the model exhibits transitional dynamics and fiscal policy crucially determines the speed of (regional) convergence. The analysis of regional differences in financial and human wealth uses ideas recently developed in Caselli and Ventura (1999), and the solution technique employs the method of backward integration developed in Brunner and Strulik (1998).

The remainder is structured in six sections. Section 2 lays out the basic theoretical framework. Section 3 discusses interregional and economy-wide dynamics. Section 4 deals with fiscal redistribution. Section 5 presents numerical solutions for a calibrated model while Section 6 analyses an extended model allowing for unemployment. Section 7 provides some conclusions and discusses limitations of the approach followed in the paper.

2. THE MODEL

2.1. Firms

In each region there exists a large number of identical firms. They operate under perfect competition and employ private capital $k_i$ and labour $l_i$ to produce an output $y_i$ with constant returns to scale in privately provided factors. Malleable output can be either used for consumption, private investment or public expenditure, and the production function has the Cobb-Douglas form:
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\[ y_i = A_i k_i^\alpha \]  \quad i = W, E. \quad 0 < \alpha < 1 \quad (1)

The productivity parameter \( A_i \) is exogenous to the firm but partly determined by productive government spending. The price of goods is normalized to one. Firms control labour inputs \( l_i \) and investment \( I_i \). With depreciation rate \( \delta > 0 \) the capital stock develops according to

\[ \dot{k}_i = I_i - \delta k_i \quad (2) \]

Firms have to pay a corporate tax on cash flow with constant rate \( \tau \). They maximize the present value of their intertemporal net profit flow

\[ V_i(0) = \int_0^\infty \exp[-r_i(t) t] \{ (1 - \tau) [y_i - w_i l_i] - I_i \} dt \]

subject to (2), where \( w_i \) denotes the wage rate and

\[ r_i(t) = \frac{1}{t} \int_0^t r_i(s) ds \quad (3) \]

is the average interest rate between times 0 and \( t \). According to the first-order conditions, factor prices are given by

\[ w_i = (1 - \alpha) A_i (K_i / L_i)^\alpha \quad (4) \]

and

\[ r_i = (1 - \tau) \alpha A_i (K_i / L_i)^{\alpha - 1} - \delta \quad (5) \]

In writing (4) and (5) we have used the fact that all firms are identical and hence choose a capital-labour ratio that equals the capital-labour ratio of their region, \( k_i/l_i = K_i/L_i \).

2.2. Government behaviour

The government taxes corporate income and individual income with a single rate. To avoid double taxation individual interest earnings are tax exempt. Tax earnings are at least partly spent on the accumulation of productive public capital \( G_i \). The remainder is spent on transfer payments within a region, \( Z_i \), and intra-regional transfers. The government runs a balanced budget which can be written as

\[ \tau (Y_W + Y_E) = \dot{G}_W + \delta G_W + \dot{G}_E + \delta G_E + Z_W + Z_E \quad (6) \]

where \( \delta \) is the depreciation rate of public capital which is assumed to be the same as for private capital. The analysis simplifies greatly if we assume a two-step procedure in government budgeting. In the first step the government

1. The assumed tax system guarantees that every unit of income produced is taxed exactly once with a constant rate. Therefore, the model is compatible with the widespread assumption of a single tax rate on income in models of growth and taxation. The tax rate itself can be interpreted as the government share in GDP.

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decides separately for each region how to spend regional tax earnings. In the second step it performs interregional redistribution according to a system of fiscal equalization (Länderfinanzausgleich). With $0 \leq q_i \leq 1$ denoting the share spent on productive services and $x$ denoting the fraction of western tax earning transferred to the East, government behaviour can be summarized as

$$
\begin{align*}
\dot{G}_i &= q_i \tau Y_i - \delta G_i \\
Z_W &= (1 - q_W - x) \tau Y_W \\
Z_E &= (1 - q_E) \tau Y_E + x \tau Y_W
\end{align*}
$$

(7)

We follow Barro (1990) in assuming decreasing returns of infrastructure so that the macroeconomy exhibits constant returns to scale in private and public capital. Since the regions differ in size their infrastructure has to be scaled by population size to eliminate unwanted scale effects.\(^2\) The regional factor productivity $A_i$ is then given by

$$
A_i = A(G_i/L_i)^{1-\alpha} \quad A > 0
$$

(8)

where $A$ denotes a general productivity parameter which is assumed to be identical in both regions.\(^3\)

### 2.3. Households

Western and eastern regions are populated by a large number of households, numbered $j = 1, 2, \ldots, L_W$ and $j = 1, 2, \ldots, L_E$, respectively. Each household supplies one unit of labour inelastically and maximizes utility from intertemporal consumption

$$
U_i = \int_0^\infty \frac{c_i^{\beta-\sigma} - 1}{1 - \sigma} e^{-\rho t} dt
$$

(9)

subject to his budget constraint

$$
c_i + \hat{a}_i = r_i a_i + (1 - \tau) w_i + z_i
$$

(10)

where $\rho$ denotes the time preference rate, and $\sigma^{-1} < 1$ is the intertemporal elasticity of substitution. Individuals may differ in their initial endowment of financial wealth $a_i(0)$ and in their received transfers, $z_i$. The heterogeneity in wealth may explain the existence of intra-regional transfers. From the first-

2. It is not the absolute quantity of infrastructure but the provided infrastructure per inhabitant which influences productivity. Hence, we assume that productivity increases, for example, due to an increase of miles of roads per inhabitant, i.e. per driver, but does not increase if roads and inhabitants increase in equal size leaving miles of roads per inhabitant unchanged. We assume, therefore, that there exists no mere scale effect of a unification of regions.

3. Equation (8) introduces a mechanism through which infrastructure provided by the government affects the productivity of privately owned factors. The empirical paper by Duggal et al. (1999) provides a rationale for the chosen specification.

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order conditions of the corresponding current-value Hamiltonian we obtain the Ramsey rule

$$\frac{\dot{c}_i}{c_i} = (r_i - \rho)/\sigma$$  \hspace{1cm} (11)

which applies to all consumers independently from wealth or provenance.

2.4. A fiscal policy rule for economic convergence

Unification induces a spontaneous equalization of regional interest rates through capital movements towards the region with the higher net marginal product of private capital. Applying the interest parity on (5) and using (8) yields

$$\theta \equiv \frac{y_E}{y_W} = \frac{K_E/L_E}{K_W/L_W} = \frac{G_E}{G_W} \frac{1}{\lambda}$$ \hspace{1cm} (12)

where

$$\lambda \equiv \frac{L_E}{L_W}$$ \hspace{1cm} (13)

Equations (12) and (13) introduce two measures of regional differences. The first one, $\theta$, measures the relative backwardness of the eastern region in terms of eastern income per capita relative to western income per capita. The second one, $\lambda$, is a scale variable that controls for the size of the regional workforce.

Equation (12) displays the basic mechanism of the model: interregional mobile private capital ties down the East’s relative income per capita to its relative stock of infrastructure per capita. If, for example, the pre-unification levels of private and public capital per capita were $K_E/L_E = 0.4K_W/L_W$ and $G_E/L_E = 0.5G_W/L_W$, then unification would lead to a spontaneous reallocation of private capital from the West to the East so that $K_E/L_E = 0.5K_W/L_W$ and hence $\theta = 0.5$. For simplicity we assume that any possible difference in the region’s relative endowment with private and public capital are equalized by private capital flows at unification time so that the starting point of the analysis is uniquely determined by the regional distribution of infrastructure. 4

Consider now a government that simply adopts the ‘successful’ western policy in the eastern part of the country, i.e. $q_E = q_W$. After insertion of (8) and (12) into (7) we obtain

$$\gamma_{\theta} \equiv \frac{\dot{\theta}}{\theta} = (q_E - q_W)\frac{A(G_W)^{-\omega}}{K_W}$$ \hspace{1cm} (14)

Hence, there will never be convergence if the richer region’s fiscal policy is imposed upon the poorer region. In conclusion, infrastructure spending in the poorer region must be temporarily higher to attract private capital. The following proposition shows the policy rule that establishes income convergence between the East and the West.

4. The instantaneous relocation of private capital occurs because the model does not contain any adjustment costs.
Proposition 1. Consider the two-region endogenous growth model as described above. Let the eastern region be initially backward in terms of per capita income relative to the western region. Then the unique set of monotonous fiscal policy functions which establish economic convergence is determined by

\[ q_E = \left| f(\theta) + 1 \right| q_W \quad f' < 0 \quad f(1) = 0 \]  

The proof inserts (15) into (14). In the remainder of the paper we assume that the government has the objective to realize regional convergence and, therefore, adopts a policy rule from the set of feasible functions (15). Note that the policy does not depend on time but on the state of the system, namely the distance of the East from its western counterpart so that it constitutes a time-consistent credible policy.

3. ECONOMIC CONVERGENCE

3.1. Interregional and economy-wide dynamics

From the country-wide perspective any income which is not spent on infrastructure accumulation is spent on either consumption, \( C \), or private capital accumulation, \( K \). Hence the economy-wide private capital stock

\[ K = K_W + K_E = (1 + \theta \lambda) K_W \]  

develops according to

\[ \dot{K} = (1 - \tau q_W) A \left( \frac{G_W}{K_W} \right)^{1-\alpha} K_W + (1 - \tau q_E) A \left( \frac{G_E}{K_E} \right)^{1-\alpha} K_E - C - \delta K \]  

Let the economy-wide consumption-capital ratio be defined as \( \chi \equiv C/K \) and western infrastructure per unit of total private capital as \( g_W \equiv G_W/K \). Using (12), (15) and (16), equation (17) can be rewritten as

\[ \gamma_K \equiv \dot{K}/K = (1 + \theta \lambda - \tau q_W [1 + \lambda (f(\theta) + 1)]) A g_W^{1-\alpha} (1 + \lambda \theta)^{-\alpha} - \chi - \delta \]  

Employing (5) and (10) we obtain in the same way

\[ \gamma_C \equiv \dot{C}/C - \gamma_K = \frac{1}{\sigma} [(1 - \tau) \alpha A g_W^{1-\alpha} (1 + \lambda \theta)^{-\alpha} - (\delta + \rho)] - \gamma_K \]  

and (7) and (14) can be rewritten as

\[ \gamma_{g_W} \equiv \dot{g}_W/G_W - \gamma_K = q_W \tau A g_W^{\alpha} (1 + \lambda \theta)^{-\alpha} - \delta - \gamma_K \]  

With equations (18)–(21) the economy is described by a three-dimensional differential equation system in \( \theta, g_W \) and \( \chi \).
3.2. Equilibrium analysis

At the equilibrium we have $\theta' = 1$ from (21). After insertion of (20) into (19) the equilibrium value of $g_W$ is determined by the implicit function

$$0 = F(g_W) = (1 - \tau)\alpha A g_W^{1-\alpha}(1 + \lambda)^{1-\alpha} - (\delta - \rho)/\sigma - q_W \tau A g_W^{\alpha}(1 + \lambda)^{-\alpha} + \delta$$

(22)

Since $F' > 0$ for all positive $g_W$ and $\lim_{g_W \to 0} F(g_W) = -\infty$ and $\lim_{g_W \to 0} F(g_W) = \infty$, a unique equilibrium $g_W^*$ exists. At this equilibrium $\chi'$ is obtained as

$$\chi^* = (1 + \lambda)^{1-\alpha} A g_W^{1-\alpha}(1 - \tau)q_W - (1 - \tau)\alpha/\sigma + (\delta + \rho)/\sigma - \delta$$

(23)

from (18) and (19). Generally, (22) can only be solved numerically. It is, however, useful to consider for a moment the special parameterization $\rho = (\sigma - 1)\lambda$ for which $g_W^*$ can be obtained analytically as

$$g_W^* = \frac{\sigma q_W \tau}{(1 - \tau)\alpha(1 + \lambda)}$$

(24)

After insertion into (19) the equilibrium growth rate of the economy is calculated as

$$\gamma_c = \left[\alpha(1 - \tau)/\sigma\right] A(q_W \tau)^{1-\alpha} - \delta$$

(25)

By derivation with respect to $\tau$ it can be verified that the long-run growth maximizing tax rate is $\tau = 1 - \alpha$.\(^5\) Hence, Barro’s (1990) finding that the optimal income tax rate equals the production elasticity of infrastructure is replicated in the two-regime growth model with inter- and intra-regional transfers.

The Jacobian determinant at the steady state is computed as

$$\det J = \partial r_0/\partial \theta[\partial r_0/\partial g_W - \partial r_1/\partial g_W]$$

with

$$\frac{\partial r_0}{\partial \theta} = f''(\theta)(1 + \lambda)^{-\alpha} q_W \tau A g_W^{-\alpha} < 0$$

$$\frac{\partial r_0}{\partial g_W} = \frac{\partial r_1}{\partial g_W} = -\alpha(1 + \lambda)^{-\alpha} q_W \tau A g_W^{\alpha-1} - (1 - \alpha)(1 - \tau)(1 + \lambda)^{1-\alpha} A g_W^{\alpha}/\sigma < 0$$

so that the equilibrium is a saddlepoint. The eigenvalues are

$$\lambda_1 = \frac{\partial r_0}{\partial \theta} < 0$$

---

\(^5\) The empirical literature on economic growth, dominated by cross-country regressions and tests of income convergence across countries, has recently been enriched by studies that provide direct tests of endogenous growth models utilizing time-series data. Kockelkoren and Yi (1997) have recently provided empirical evidence for the US and the UK that permanent changes in fiscal policy can have permanent effects on growth rates even though the growth rate itself appears stable over time.
and

\[ \lambda_{2,3} = \left( 1 + \frac{\partial \gamma_x}{\partial g_L} \pm \sqrt{\left( 1 + \frac{\partial \gamma_x}{\partial g_L} \right)^2 - 4 \left( \frac{\partial \gamma_x}{\partial g_L} - \frac{\partial \gamma_x}{\partial g_W} \right) / 2} \right) \]

Since \( \frac{\partial \gamma_x}{\partial g_L} - \frac{\partial \gamma_x}{\partial g_W} < 0 \) all eigenvalues are real and two eigenvalues are negative, so that adjustment towards the equilibrium is monotonous on a two-dimensional stable manifold.

At the steady-state consumption, public capital and private capital grow with identical rates economy-wide, which can be seen from (19) and (20), as well as in its regional components, which can be seen from (11) and (12).

**4. INTERREGIONAL INCOME REDISTRIBUTION: THE SOLIDARITY PACT**

The problem of regional convergence has been solved independently from the existence of interregional income redistribution. So far, however, we have only discussed the convergence of regional income produced but not the problem of convergence of income earned, i.e., the convergence of regional wealth and regional consumption. For that purpose let us now compare the average individual in the East with its counterpart in the West. From (7) we see that the average western individual receives income transfers

\[ z_W = Z_W/L_W = (1 - q_W - \tau) Y_W/L_W \]

and the average eastern individual receives

\[ z_E = (1 - q_E) Y_E/L_E + x \tau Y_W/L_E \]

With use of (4) and the definitions of \( \theta \) and \( \lambda \) their budget constraints (10) can be written as

\[ \hat{a}_W = (1 - \alpha(1 - \tau) - q_W \tau - x \tau) y_W - c_W + ra_W \] \hspace{1cm} (26)

\[ \hat{a}_E = (1 - \alpha(1 - \tau)) \theta - q_E \tau \theta + \frac{x \tau}{\lambda} y_W - c_E + ra_E \] \hspace{1cm} (27)

After integrating (26) and (27) and substituting the integrated version of (11) we arrive after some amount of algebra at

\[ \frac{c_E(t)}{c_W(t)} = \frac{c_E(0)}{c_W(0)} = \frac{a_E(0) + \int_0^\infty \theta - q_E \tau \theta + (x \tau / \lambda) y_W \exp \left[ - \int_0^t \tau dv \right] dt}{a_W(0) + \int_0^\infty (1 - \alpha(1 - \tau) - q_W \tau - x \tau) y_W \exp \left[ - \int_0^t \tau dv \right] dt} \] \hspace{1cm} (28)

The first sign of equality originates from the fact that all individuals choose the same intertemporal allocation of consumption. Regional levels of consumption converge if the right-hand side of the equation equals one.
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Let us first consider a government that attempts to realize convergence of consumption and the hypothetical case of spontaneous economic convergence at unification time. In this case the integrals in (28) are identical for \( x = 0 \) but even then the eastern individual would be worse off if he brings along a lower initial endowment of financial wealth. The only possibility to produce convergence of consumption is to partly expropriate the western individual. Suppose, for example, that \( K_E/L_E \) equals \( 0.5K_W/L_W \) before unification and that all eastern capital is owned by the eastern population so that the average eastern individual is half as rich in terms of financial wealth as his western counterpart. If the westerner donates half of his wealth to the easterner then \( a_E(0) = a_W(0) \) and \( c_E = c_W \) for all \( t \).

This leads to the following conclusion. While equating the \( a_i \)'s means to compensate the eastern individual for the bad performance of his economy before unification, equating the integrals means to compensate the eastern individual for the relatively bad performance of his native region after unification. We have emphasized this distinction to motivate the following assumption about government behaviour. The government does not take responsibility for the bad performance of the eastern region before unification but takes responsibility for the well-being of eastern individuals after unification. Formally this means that the government tries to equalize consumption levels of individuals with initially equal financial wealth, i.e. it tries to equalize consumption levels as if the eastern individuals are initially equally equipped with financial wealth.

Assuming that the government compensates only disadvantages which originate from living in the poorer region after unification is of course a highly normative judgement but it has a very useful implication. Since equating the integrals means equating human wealth or intertemporal non-financial income the income transfer policy prevents regional migration. Although this applies in a strict sense only to the average eastern individual it is generally possible to construct a deliberate spending policy that realizes the result for all individuals once their specific individual economic situation is known. In turn, any policy that tries to compensate for different initial \( a_i \) may lead to migration of western individuals to the East in order to receive transfers that make them at least partly better-off for their initial loss in financial wealth.

A policy \( x \) that equates the integrals and does not depend on time but on the state of the system, given by \( \theta \), consists of equating the terms in brackets in (28), i.e. equating the current non-financial disposable income in both regions. After inserting the income convergence policy (15) we obtain this income transfer policy as

\[
x = \left\{ \left[ 1 - \alpha(1 - \tau) - q_W\tau(1 - \theta) + f(\theta)q_W\tau\theta \right] \frac{\lambda}{\tau(\lambda + 1)} \right\}
\]

(29)

6. The assumption seems reasonable since the German mainstream parties are overwhelmingly dominated by western politicians.

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The magnitude of transfers depends on the chosen policy to achieve economic convergence. The policy rule implies that transfers will have an end when income per worker has converged, \( \theta = 1 \Leftrightarrow x = 0 \). Transfers decline with increasing degree of economic convergence, \( \partial x / \partial \theta < 0 \), and will be the lower the smaller the poorer region.

5. MODEL CALIBRATION AND SOLUTION TECHNIQUE

The model is calibrated so that its steady-state solution matches West Germany's pre-unification's performance. Unless otherwise specified the data are taken from Statistisches Bundesamt (1997). From the Eastern and Western population size we calculate \( \lambda = 0.25 \). We set \( \tau = 0.5 \) from Western Germany's government share and \( q_W = 0.1 \) from the average pre-unification value of West Germany's infrastructure share in government spending. From numerous other calibration studies we adopt \( \rho = 0.02 \).

Because \( \alpha \) simultaneously determines productivity of labour, private capital and infrastructure, any numerical specification entails a shortcoming. Since the regional distribution of labour is fixed, and private capital is allowed to flow freely from region to region, differences in regional growth are determined by the distribution of infrastructure and the production elasticity of infrastructure is identified as the most decisive one in our model. We therefore decided to calibrate \( \alpha \) to match the infrastructure elasticity. Although there is some confusion in the empirical literature about the true value of the infrastructure elasticity, the comprehensive compilation of empirical studies in Sturm et al. (1998) finds that most researchers estimate an elasticity between 0.1 and 0.3. This leads us to the definition of a basic scenario with an infrastructure elasticity of 0.2 \((\alpha = 0.8)\) and the introduction of an alternative scenario with \( \alpha = 0.7 \) in order to analyse the sensitivity of results with respect to the choice of the infrastructure elasticity.

The remaining parameters, \( A, \delta \) and \( \sigma \) are specified so that the model meets West Germany's pre-unification capital–output ratio, which was on average about 2.7 over the last decades, and its per capita income growth rate. West Germany, however, was itself far away from its long-run equilibrium path for most of the time after the Second World War and the economy was catching up with comparatively high growth rates. Hence, we select the average growth rate during the 1980s, which was 1.75 per cent, to be met by the model's steady-state growth rate. This leads to the specification of \( \sigma = 2.5, \delta = 0.08 \) and \( A = 0.504 \) which results in \( g_{t}^* = 0.175 \) and \( (K/Y)^* = 2.78 \). In the alternative scenario a value of \( A = 0.655 \) results in the same long-run growth rate and \( (K/Y)^* = 2.45 \). While the second scenario underestimates the empirical capital–output ratio it provides a better result for the steady-state ratio of public to private capital, which was around 0.28 in the 1980s in West Germany (DIW, 1994, p. 458). Table 1 summarizes the alternative parameterizations.
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Table 1 Model parameterizations

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>$\lambda$</th>
<th>$\tau$</th>
<th>$q_{W}$</th>
<th>$\epsilon$</th>
<th>$\rho$</th>
<th>$\sigma$</th>
<th>$A$</th>
<th>$\gamma^*$</th>
<th>$(K/Y)^*$</th>
<th>$(G_i/K_i)^*$</th>
</tr>
</thead>
<tbody>
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<td>0.8</td>
<td>0.25</td>
<td>0.50</td>
<td>0.1</td>
<td>0.08</td>
<td>2.5</td>
<td>0.504</td>
<td>1.75%</td>
<td>2.78</td>
<td>18.4%</td>
<td></td>
</tr>
<tr>
<td>0.7</td>
<td>0.25</td>
<td>0.50</td>
<td>0.1</td>
<td>0.08</td>
<td>2.5</td>
<td>0.655</td>
<td>1.75%</td>
<td>2.45</td>
<td>21.1%</td>
<td></td>
</tr>
</tbody>
</table>

Our analysis begins after the collapse of the former GDR, i.e. after the initial slump of the eastern economy, so that $t = 0$ in model time corresponds approximately to 1992 in real time, and our model is therefore now situated in year 7 after unification. In 1992 the private capital stock as well as the public capital stock per capita in East Germany was approximately 40 per cent of the corresponding western level, i.e. our analysis starts at $\theta = 0.4$.\footnote{Data for private capital are from DIW (1995, p. 540), data for public capital are available in DIW (1994, p. 461).}

The fiscal policy rule is specified as

$$f(\theta) = a \left[\frac{1 - \theta}{\theta}\right]^\epsilon \quad (30)$$

where, broadly speaking, the parameter $a$ controls the absolute weight given to infrastructure expenditure and $\epsilon > 0$ controls the policy reaction on relative income improvements. A higher $\epsilon$ specifies a more reluctant fiscal policy at higher $\theta$'s, i.e. when the eastern economy has already caught up with parts of its initial backwardness. We set $\epsilon = 1$ in the basic scenario and consider an alternative policy with $\epsilon = 1.5$. The choice of $\epsilon$ and the actual government spending policy at $t = 0$ determine the value of $a$, so that (30) meets the actual fiscal policy after unification.

Relating the data on government investment in DIW (1995, p. 537) to eastern GDP in the corresponding years we calculate infrastructure investment in eastern Germany of between 9 and 10 per cent of East Germany's GDP in the early 1990s, so that $0.1 = \tau q_f$ implies $q_f(0) = 0.2$ and $a = \frac{2}{3}$ for the basic fiscal policy rule and $a = 0.5443$ for $\epsilon = 1.5$.

After inserting (30) and the parameters from Table 1 in (29) the initial share of transfers to the East in western tax earnings is obtained as

$$x(0) = \left\{1 - 0.8 \cdot (1 - 0.5) - 0.1 \cdot 0.5 \right\} \left[1 - 0.4 \right] + 0.5 \cdot 0.1 \cdot 0.4 \cdot 1 \left[\frac{0.25}{1.25 \cdot 0.5}\right]$$

$$= 14\%$$

The existence of a two-dimensional stable manifold provides us with a further advantage in modelling unification. It enables us to specify a second initial condition, which identifies a unique adjustment path from the feasible set of trajectories on the manifold. Under the assumption that West Germany was approximately developing on its steady-state growth path its public to...
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private capital ratio before unification is implicitly determined by the steady-state after unification through \( G_W(0)/K_W(0) = g_*^W(1 + \lambda) \) and hence \( g_W(0) = g_*^W(1 + \lambda)/(1 + \theta(0)\lambda) \).

We solve the numerical problem with the method of backward integration as described in Brunner and Strulik (1998). The main feature of the method is that it reveals – besides arbitrarily small discretization errors – the exact adjustment path rather than approximations. After having obtained the adjustment path we use (1), (8), (13) and (16) to recalculate regional growth rates as

\[
\begin{align*}
\gamma_{K_W} &= \gamma_K - \gamma_\theta \frac{\theta \lambda}{1 + \lambda \theta} \\
\gamma_{K_E} &= \gamma_{K_W} + \gamma_\theta \\
\gamma_{S_E} &= \gamma_\theta + \gamma_{S_W} \\
\gamma_{Y_W} &= (1 - \alpha)\gamma_{S_W} + \gamma_{K_W} \\
\gamma_{Y_E} &= (1 - \alpha)\gamma_{S_E} + \gamma_{K_E}
\end{align*}
\]

(31)

5.1. Results

Eastern and western Germany’s development and convergence in the basic scenario is described by the solid lines in Figure 1. The first panel on the left shows the fiscal policy \( q_E(\theta) \) as implied by (30). The other panels show the resulting time paths for several interesting variables. The main variable of interest, the degree of backwardness of the eastern region, is shown in the first panel on the right-hand side. In the basic scenario half of the initial gap between East and West is closed after about ten years after unification and after about 30 years the eastern region shows 90 per cent of the productivity of its western counterpart.\(^8\)

Bearing in mind that the starting point in real time was 1992 the eastern economy has now, 1999, reached 63 per cent of West Germany’s productivity level.

The third panel shows the implied income transfer policy. In the years shortly after unification average transfers approximately met the historical data with a tax share of about 14 per cent initially and of about 8.5 per cent after seven years. However, while average transfers are compatible with the empirical data this is not true for the development of transfers over time.\(^9\) Nevertheless, even under the model’s successful convergence policy income transfers are

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8. This prediction is similar to the simulation results in Burda and Funke (1995). On the contrary, Barro (1991), Barro and Sala-I-Martin (1991), Dornbusch and Wolf (1992), and Hughes Hallett and Ma (1993) have predicted that convergence of living standards will take much longer. On the contrary, Keller (1997) is more optimistic, predicting that 75 per cent of the initial difference in output per capita will be eliminated in 20 years.

9. The figures in Deutsche Bundesbank (1996, p. 19) show that the total amount of transfers from western to eastern Germany sums up to approximately 5 per cent of West Germany’s GDP per year over the first six years after unification. Using \( r = 0.5 \) this implies an \( x \) of 10 per cent during this period.

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Figure 1  Economic development after German unification
Notes: Solid lines: basic scenario; dashed lines: $\alpha = 0.7$; dotted lines: reluctant fiscal policy.

significantly positive for a long time. For example, 15 (25) years after unification the eastern region still receives approximately 5 (2.7) per cent of western tax earnings.

The next panel shows the development of regional private capital. The improvement in eastern infrastructure productivity goes hand-in-hand with large private investments in this region. The capital growth rate is above 10 per cent shortly after unification and is still almost twice as high as its equilibrium value after 15 years. While this sentence makes sense for every economist who is familiar with the law of diminishing returns the emphasis should perhaps be different when the result is presented to the public: although the eastern economy has started with extraordinarily high growth rates, the growth rate will decrease to a third of its initial value 15 years after unification.

Capital in the eastern region is accumulated by eastern and western individuals. Realizing the increasing productivity in the eastern region, westerners allocate large parts of their investment to the East. This leads to a capital growth rate below 1 per cent in the western region during the first five years after unification. Compared to the East, however, unification has only a relatively small impact on the western region. This outcome reflects the fact
that the eastern region is much smaller in absolute size and can best be seen in
the small effect on the economy-wide interest rate which falls only about 0.3
percentage points. To understand why the interest rate approaches its steady
state from below and not from above one has to recall that private capital is
regionally mobile. Hence, productivity of private capital is bounded by the
regional productivity of infrastructure. Eastern infrastructure, however, falls
short of its equilibrium value at the moment of unification and then increases
during the convergence process.

The relatively small deviation of the interest rate from its equilibrium value
is reflected by a relatively small deviation of consumption growth from its
equilibrium value as shown in the final panel on the right.

The dashed lines in Figure 1 show the development under the $\alpha = 0.7$
assumption. The main result is depicted in the $\theta$-path which virtually coincides
with the basic scenario. Because the change in $\alpha$ affects both economies in
exactly the same way relative regional deviation remains unchanged. A lower $\alpha$
increases the importance of infrastructure accumulation in the development
process. Since the speed of accumulation is determined by the policy rule, and
the policy rule remains unchanged, both regions develop with a slightly slower
pace as compared to the basic scenario. The increased importance of
infrastructure is also reflected by a higher initial decrease of the interest rate
on private capital and hence by a higher decrease of growth rate of
consumption. In the years after unification, both Easterners and Westerners
consume more and invest less as compared to the basic scenario.\footnote{The x-panel also suggests that a lower $\alpha$ implies a slight increase of transfers. Since $\epsilon' = 1 - \alpha$}

The dotted lines in Figure 1 represent the outcome of the basic
parameterization under the reluctant fiscal policy with $\epsilon = 1.5$. As shown in
the $q_t$ panel the government puts less weight on infrastructure development
after the economy has already caught up with parts of the initial gap. As a result
the convergence process is similar during the jumpstart periods but slows down
more quickly. The date is guesswork, of course, but according to the model, 80
per cent of western productivity will be reached after 30 years (instead of 20
years). Owing to the slower speed of convergence, transfer payments will be
almost twice as high 20 years after unification.

6. WAGE SETTING AND UNEMPLOYMENT

An extension of the model with wage-setting behaviour is an interesting task
for several reasons. First, in the jumpstart years Germany's unions successfully
carried out a wage policy that moved eastern wages far out of line with

\footnote{The x-panel also suggests that a lower $\alpha$ implies a slight increase of transfers. Since $\epsilon' = 1 - \alpha$; \also determines labour productivity, its change also influences the regional difference in human wealth and hence income transfers according to (28) and (29). This shortcoming would not occur if we had specified the production elasticity of labour independently from the production elasticity of infrastructure.}
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productivity.\textsuperscript{11} Hence, the inclusion of wage-setting behaviour and un-
employment provides a more realistic adjustment scenario. Furthermore, it is
an interesting question in itself to what extent the introduction of un-
employment alters the pace of development compared to the market
equilibrium solution. Finally, it is interesting to identify the winners and losers
eastern wage-setting behaviour. One frequently cited proposition is that the
union wage policy was advised (if not imposed) by western umbrella
organizations for the sake of its western members. The $\gamma_{Kf}$, $\gamma_{Kw}$-panel of Figure
1 seems to support this proposition. The western worker is clearly a double loser
of unification. He has not only to suffer the loss of parts of his social transfers
which are now used to compensate his eastern neighbour for his relatively bad
initial position, but he also loses potential wage increases. Because firms invest
in western Germany with a rate below the steady-state value, western
productivity and wages grow with a rate below steady-state growth during the
convergence period. Since we have assumed that West Germany was
developing approximately on its steady state before unification, this finding
implies that western wages grow slower than they would have grown without
unification. If lower investment in East Germany implies more investment in
West Germany, western unions may have reason to prefer high wage growth in
eastern Germany to protect their own workers.

When introducing wage-setting behaviour we have to distinguish between
population size and workforce, and income per capita and income per worker.
Let $\bar{L}_E$ define the size of the eastern population, $L_F$ the size of the actually
employed workforce, $\lambda \equiv \bar{L}_E/L_W$ the East's relative population size, and
$\hat{\lambda} \equiv L_E/L_W$ the relative size of the eastern employed workforce. While the
East's relative income per worker is, as before, denoted by $\theta$ we now have a
second measure of regional disparity, which is the East's relative income per
capita, measured by $\hat{\theta}_2$ and calculated as

$$\hat{\theta}_2 \equiv \frac{Y_E/\bar{L}_E}{Y_W/L_W} = \theta \frac{\hat{\lambda}}{\hat{\lambda}}$$

which is eastern productivity times the employment rate.\textsuperscript{12}

In order to maintain an analytically tractable model we cannot integrate
wage bargaining into the general equilibrium context but have to impose a
behavioural function describing the eastern wage development. This function

\textsuperscript{11} A microeconomic foundation for such a wage policy is given in Burda and Funke (1993).
\textsuperscript{12} Note that we have assumed that infrastructure is scaled with population size and not with
the size of the workforce, i.e. we have assumed that infrastructure productivity is measured
in miles of roads per inhabitant (driver) and not in miles per employed inhabitant (driver).
Unemployment does not increase infrastructure productivity, and hence -- in the context of
perfect capital mobility -- unemployment does not influence relative regional productivity,
i.e. the relative output per worker. It does, however, decrease output per capita, since not all
people are working any longer. This is the mechanism behind equation (32) which says that
relative regional productivity, $\theta$, must be multiplied by the relative regional employment
rate to obtain relative regional income per capita.
can be thought of as a compound of a fixed and a flexible part. Let us suppose that eastern unions and employers have agreed on a wage path that follows \( w_E = \theta^\beta w_W \), \( 0 < \beta < 1 \), so that the standard wage is above productivity level. If, for example, \( \beta = 0.4 \), eastern standard wages are 70 per cent of western wages at unification time and would reach 81.5 per cent when \( \theta \) reaches 0.6.

Private capital mobility, however, fixes East Germany's relative labour productivity to the value of its relative stock of infrastructure per capita. In consequence a relative wage of \( \theta^\beta \) would imply that nobody finds employment in East Germany. We therefore introduce a second, flexible part into the wage equation which comprises the assumption that at least some Easterners are willing to work for wages below the collectively agreed-upon level.\(^\text{13}\) It seems reasonable to assume that the discount that these workers are willing to accept increases with the unemployment rate, \( u \). This leads to the specification of the wage function as

\[
 w_E = (1 - bu)\theta^\beta w_W \quad b > 0, \quad 0 < \beta < 1
\]

It follows from the definition of \( \theta \) that \( u = 0 \) at \( \theta = 1 \), so that easterners demand and receive western wages when the eastern economy has completely converged. Hence, the long-run equilibrium remains the same as in the full-employment scenario. By noting that \( 1 - u = \hat{\lambda}/\lambda \) and applying the interest parity (12), (4) and (5) it can be seen that the eastern employment rate is unequivocally tied to the regional productivity differential:

\[
 \frac{\hat{\lambda}}{\lambda} = \frac{1}{b} \left[ (\theta^1 - \beta) + b - 1 \right]
\]

By the assumption that congestion is measured with respect to population size rather than with respect to the size of the workforce, equation (14) remains valid and, therefore, the model can still be described by the three differential equations, and large parts of the analysis can be taken over from the previous section. We simply have to substitute \( \hat{\lambda} \) from (34) for \( \lambda \) in the set of dynamic equations. Since \( \partial \lambda / \partial \theta > 0 \) the whole stability analysis still holds true and the economy converges along the two-dimensional stable manifold towards the equilibrium of income convergence and full employment.

Although the structure of the dynamic system does not change, some of our calculations derived from the dynamic paths change quite dramatically. This especially applies to the calculation of income transfers to the East. Since only \( \hat{\lambda}/\lambda \) workers are employed and receive wages the budget constraint of the average eastern individual (27) changes to

\[
 \hat{a}_F = (1 - \tau)(1 - b + b\hat{\lambda}/\lambda)\theta^\beta w_W + ra_F + (1 - q_F)\tau Y_E/L_F + x\tau Y_W/L_F
\]

\(^\text{13}\). Over recent years, however, a gradual erosion of industry-wide wage bargaining has occurred; its coverage has fallen from 54 per cent of West German companies and 72 per cent of West German employees in 1995 to 48 and 68 per cent respectively, in 1998. Only half of East Germany's employees are now covered by sector bargaining. Even IG Metall hinted in May 1999 that some element of profit-related pay might not be anathema after all; and IG Metall is following, not leading, other unions in this regard.
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The compensation for the bad performance of the eastern economy now additionally includes the damage done by wage-setting behaviour. The additional transfer can be understood as unemployment benefits. After inserting (34) and proceeding as in Section 4 we arrive at

\[ x = \left\{ 1 - \alpha(1 - \tau) - q_w \tau \left( 1 - \frac{\lambda}{\lambda} \right) + f(\theta)q_w \tau \theta \left( \frac{\lambda}{\tau(\lambda + 1)} \right) \right\} \] (36)

Full compensation transfers exceed the value obtained under the full-employment scenario (29) and are higher the higher the unemployment rate \( u = 1 - \lambda/\lambda \) is. Furthermore, the equations for regional capital development in (31) have to be rewritten as

\[ \gamma_{K_w} = \gamma_K - (\gamma_{\lambda} + \gamma_{\theta}) \frac{\lambda}{1 + \lambda} \theta \]  (37)

and

\[ \gamma_{K_e} = \gamma_{K_w} + \gamma_{\theta} + \gamma_{\lambda} \]

where \( \gamma_{\lambda} \) is the growth rate of the East's relative size of the workforce:

\[ \gamma_{\lambda} = \frac{\lambda}{\lambda} = \left( 1 - \beta \right) \frac{\gamma_{\theta} \theta^{1-\beta}}{\beta^{1-\beta} + \beta - 1} \] (38)

These additional equations fully describe the extension of the model.

For the computation of the convergence path we take all parameters from our basic scenario. Additionally, we have to specify the parameters of the eastern wage equation, which we do by selecting \( b = 1.5 \) and \( \beta = 0.4 \). This implies an initial unemployment rate of about 21 per cent. When the eastern economy has managed to catch up half of its initial gap the unemployment rate is approximately 9.5 per cent.

Figure 2 shows the results. Solid lines reproduce the outcome of the basic scenario from Figure 1 and dashed lines show the corresponding wage-setting solution. Compared to Figure 1 we have inserted two new panels showing the development of relative income per capita and the unemployment rate. For that purpose we have skipped the \( q_F \)-curve which is the same as in Figure 1 and the \( r \)-curve since its shape is also reflected by the \( \gamma_C \)-curve which is still available.

14. The initial condition of the West being on its steady-state growth path before unification is now calculated as \( g_w(0) = g_w(1 + \lambda)/(1 + \theta \lambda) \).
15. Since we assume that western workers are paid according to their productivity and neglect unemployment in the western region as well as short-time work and employment in job-creation schemes, the correct interpretation of the unemployment rate is that it shows the level at which the effective Eastern unemployment rate exceeds the Western unemployment rate. At the end of 1991, i.e. at the initial date of our analysis, the effective eastern unemployment rate was almost 30 per cent (Sinn and Sinn, 1992, p. 30) and the western unemployment rate was approximately 8 per cent.
Figure 2  German unification: wage-setting behaviour
Notes: Solid lines: basic scenario; dashed lines: wage setting; dotted lines: wage setting and reluctant fiscal policy.

We have placed the $\theta_2$ panel in the dominant upper left corner because this curve is essential to understand the remainder of Figure 2. Relative GDP per capita approaches the steady state from the much lower initial value of about 0.32 if unemployment exists. Turning towards the regional growth rates, we see that the eastern capital growth rate under unemployment exceeds the corresponding full employment value. This is because the eastern economy starts from a much more severe initial situation than before. West Germany's capital growth rate, however, is only insignificantly lower in the unemployment scenario. To understand the result it may help to reconsider equation (12). Because of free private capital movements $\theta$ is fixed by regional infrastructure policy. Lower employment in East Germany, $L_E < \bar{L}_E$, may then have two effects: a lower initial share of economy-wide private capital allocated in eastern Germany and, second, a higher capital–labour share in each existing firm in both regions. While the first effect results in a higher eastern capital growth rate along the convergence path the second effect additionally results in a lower western capital growth rate. Figure 2 shows that mainly the first effect takes place in our model economy. Hence, worsening investment conditions in East Germany mainly provoke a substitution from investment
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towards consumption rather than a substitution of investment in the East with investment in the West. This can also be seen in the $g_c$-panel. The initial growth rate of consumption is significantly lower than under perfect market conditions implying a higher initial level of consumption and a lower initial value of the interest rate.

The employed eastern worker can be identified as the winner of wage-setting behaviour. He starts with a higher wage rate as compared to perfect market conditions and experiences higher wage growth along the adjustment path. The question remains open whether the western worker benefits from eastern wage-setting behaviour. Owing to the initially higher capital–labour ratio he indeed starts with a higher initial wage as compared to perfect market conditions. Since the wage rate eventually grows with the steady-state rate, it grows with a (slightly) smaller rate on the convergence path as compared to the perfect-market scenario. Hence, eastern wage-setting behaviour provides a temporary gain in wages for the western worker. As the $x$-panel shows, the western worker pays for his temporary gain in wages with a permanent loss of social transfers that are now received by the unemployed eastern workers.

Transfers required for full compensation for eastern backwardness are now initially more than 3.5 percentage points higher than under perfect market conditions and lie significantly above the compensation rate under perfect market conditions for most of the convergence process. Hence, the model does not support the argument that eastern wage-setting behaviour has been the outcome of deliberate western union policy which takes the burden of additional transfers paid by western taxpayers into account.

If we assume that western taxpayers successfully resist full compensation for eastern unemployment, the true $x$-curve would lie somewhere between the solid and the dashed line in Figure 2. This would in turn have the implication that the unemployed eastern population also suffers from wage-setting behaviour and that there is only one group that benefits from wage setting which consists of the employed eastern population.

Let us now finally consider the worst-case scenario of our parameterized model. This comprises the assumptions of wage-setting behaviour and a reluctant infrastructure spending policy ($\epsilon = 1.5$) and is represented by the dotted lines in Figure 2. It can be seen that both assumptions together slow down the convergence process considerably. Half of the initial gap in income per capita is now closed 15 years after unification time (instead of 10 years) and after 30 years (instead of 20 years) eastern income per capita has reached 80 per cent of the western level. In addition, full compensation for a bad initial position implies that the East still receives large amounts of transfers long after unification time. For example, 20 years after unification the East still receives more than 7 per cent of western tax earnings. Persistent high transfers are necessary because the initially high unemployment rate decreases only slowly under the reluctant infrastructure spending scheme. For example, 10 (20) years after unification the eastern unemployment rate is still above 11 (7) per cent. In other words, the bill for the East will stay huge into the next decade.

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7. CONCLUSION

The paper has analysed economic growth and regional convergence of unified Germany within a two-region endogenous growth model. The model has emphasized the importance of public and private capital accumulation in the initially backward region and on the fiscal interdependence of both regions and its implications on regional convergence of income produced as well as income earned per inhabitant. To keep the analysis tractable several other factors which certainly also influence the convergence process have been neglected. Some of these factors – like, for example, international capital movements and migration – may enhance the speed of convergence while other factors – like initially inappropriate human capital the workforce – may slow down the adjustment pace.

The theoretical part of the paper has developed a set of feasible fiscal policy rules which establish income per capita convergence. A verbal translation of the feasible policy is: whenever infrastructure per capita in one region is lower as in the other region spend a higher share of tax earnings on infrastructure in this region. If this is not the case spend regionally identical shares. Looking back to the huge injection of public cash shows that Germany’s government has followed this rule. The general fiscal policy rule, however, neither provides information about the speed of convergence nor does it specify the involved costs for citizens of the initially richer region. For that purpose we have calibrated the model with German data. Assuming a government that has the objective to compensate the eastern population for the relatively bad performance of its economy during the adjustment period, a major finding was that actual transfers paid by western taxpayers would have been approximately sufficient for full compensation, i.e. the equalization of human wealth in both parts of Germany in a perfect-market scenario. After introducing wage setting and unemployment in the eastern region we found that actual transfers are no longer sufficient for full compensation for initial backwardness.

The speed of convergence depends on the future effort in infrastructure accumulation in the East. We have introduced alternative fiscal policy rules which are approximately consistent with the past but generate different patterns of future development. In all cases the eastern economy converges quite fast. In the most optimistic scenario it will reach 80 per cent of West Germany’s GDP per capita after 20 years. If future governments follow a

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16. See e.g. Young (1994) for the importance of factor accumulation for catching-up processes.
17. In some ways, under direct pressure, the East is setting the West a positive example. Most eastern companies have now broken out of the straitjacket of nationwide wage bargaining first foisted on them by the West: easterners work long hours and are more flexible than western workers; red tape has been slashed.
18. The importance of fiscal policy in the model does, of course, not imply that there is no need to streamline the bewildering array of investment promotion schemes since a significant part of the early tax-driven investment in the East went, in effect, down a black hole.
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reluctant infrastructure expenditure policy and persistent high unemployment exists, 80 per cent will be reached about ten years later.

Why do we think that the results obtained indicate a quite fast adjustment of the eastern economy? For a better understanding it may help to compare East Germany's growth performance with West Germany's *Wirtschaftswunder* after the Second World War. In real international dollars West Germany's GDP per capita was 40 per cent of the corresponding US level in the initial period 1950–55 (data from Summers and Heston, 1995). During this time the private investment/GDP ratio reached values between 20 and 25 per cent. For the East German economy that started at a similar initial position we calculate a private investment ratio between 38 and 20 per cent during the first five years in our unemployment scenario, a value approximately consistent with the actually attained empirical values. In 1990, 40 years after the onset of the German *Wirtschaftswunder*, West Germany had reached 80 per cent of the US GDP per capita. In comparison, our analysis suggests that eastern Germany may converge much faster and may have caught up 80 per cent of its initial gap to West Germany's GDP per capita after 20 years. This process may even speed up when more employees agree to add more flexibility to the one-size-fits-all system of collective bargaining and therefore allow firms to adjust to their own market conditions.

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