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The Macroeconomic Effects of German Unification: Real Adjustments and the Welfare State[1]

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We study the effects of German unification in a model with capital accumulation, skill differences, and a welfare state. We argue that this event is similar to a mass migration of low-skilled agents holding no capital into a foreign country. Absent a welfare state, we observe an investment boom, depressed output, and employment conditions. Capital owners and high-skilled agents are willing to give up to 4% of per-capita consumption to favor unification. When a welfare state exists the investment boom disappears and the recession is prolonged. Now, with unification, capital owners and high-skilled agents lose 4% of per-capita consumption. *Journal of Economic Literature* Classification Numbers: E32, E62, F22, H23.

Key Words: German unification; capital accumulation; skill differences; credit constraints; the welfare state.

I Want My Wall Back. A Graffiti in East Berlin

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1. INTRODUCTION

The fall of the Berlin wall and the unification of the two Germanies in July 1990 were phenomenal disturbances rarely experienced in modern economies. The macroeconomic adjustments that followed were strongly recessive: output per-capita declined substantially, the unemployment rate increased up to 12%, the tax burden on West German residents raised dramatically, and the current account balance turned severely negative. Several analysts (see, e.g., The Economist, 1996) believe that the imposition of a one-to-one exchange rate between the two marks, the attempt to induce wage parity between the East and the West, and the federal fiscal expansion to finance the reconstruction in the East together with the tight corset of the Maastricht treaty contributed to retarding the adjustment and strengthen the recessive output and employment effects of the disturbance.

In this paper we examine the macroeconomic consequences of German unification and measure the resulting welfare changes with a dynamic general equilibrium model. Our model focuses attention on three key aspects of unification. First, we assume that the two Germanies differed in their capital holdings. This agrees with the fact that most of the capital stock of the former GDR was obsolete or unusable for production in a market economy (see Siebert, 1990; Akerlof *et al*., 1991; and Sinn and Sinn, 1992). Second, we assume that the average skill level in the former GDR was lower than in the former FDR. Soskice (1994) shows that although the average length of schooling was higher in the former GDR than in many OECD countries, most East Germans had to be retrained after unification. Furthermore, even after having been retrained, many East German workers still do not fit the profile of West German semi-skilled workers. Bertocchi and Spagat (1998) also show that the training of East German workers was dominated by vocational activities, a finding indicating that workers' human capital was organization-specific and not easily adapted to Western style of production. The final important part of our analysis is the explicit modelling of a welfare state. One of the distinguishing features of German unification was the large amount of transfers from the West to the East. The introduction of the "solidarity tax" in 1991 and the increase of labor market contributions might be important features to understand the consequences of German unification.

We argue that the process of unification represents a formidable shock to the West German economy, qualitatively similar to a sudden 26% increase in the low-skilled portion of the population. Since the population growth rate temporarily increases, the capital-labor ratio decreases and the economy devotes resources to rebuild the per-capita capital stock. In addition, because former East Germans are assumed to be low-skilled, the

composition of the workforce temporarily changes and this generates further important short-run dynamics.

We show that if newcomers have lower productivities than the average natives, output per-capita, capital, and hours in efficiency units fall; total and high-skilled hours increase and investment per-capita temporarily increases and then falls over the adjustment path. We also show that if high- and low-skilled workers are an imperfect substitute in production, a large wage premium ensues after unification and the resulting income effect substantially curbs both the initial investment boom and the increase in high-skilled hours. The persistence of these effects depends on the length of time that it takes for the skill distribution to readjust to the pre-unification situation. Given the typical time needed for migrants to acquire the same distribution of skills as the native population, and the estimated time needed to retrain East Germans, the model predicts a prolonged period of below steady state conditions with depressive effects still active 30–40 years after the unification (see also Hughes-Hallett and Ma, 1993).

The qualitative nature of these short run adjustments is similar to that experienced by Germany after reunification (output and capital per-capita decline, employment falls, fixed investment first increases and then falls) but, quantitatively, the recessionary effects produced by the model are smaller than those observed in Germany in the 1990s. When we introduce a government whose only task is to redistribute income across classes of agents in such a way either to keep the relative income level constant over the adjustment path (egalitarian welfare state) or to insure low-skilled agents from income fluctuations (insurance welfare state), the outcomes are closer to those experienced in Germany. We show that such redistributive schemes alter investment opportunities and lower or even eliminate the short-run boom in investment per-capita previously observed, inducing a deeper and prolonged recession. We argue that welfare provisions of exactly the type we consider have been mentioned in the literature as a main difference between the transition process in East Germany and in other formerly centrally planned economies (see, e.g., Schrettl, 1992). These policies lower the incentives to invest producing a drop in capital formation and income per-capita growth both instantaneously and over the adjustment path relative to the case of a no welfare state.

Who benefits from the unification? In the absence of a welfare state, low-skilled agents lose because their real wages decrease temporarily. High-skilled agents benefit from the temporary increase in the return on their capital holdings but are also affected by the change in wages over the adjustment process. The magnitude and the sign of this latter effect depends crucially on the elasticity of substitution between high- and low-skilled labor. When they are perfect substitutes in production, the

high-skilled wage decreases and unification actually lowers high-skilled agents' welfare. When the elasticity of substitution is lower, high-skilled agents enjoy an increase in welfare (with a gain of up to 4% of per-capita consumption). These results are similar, but not identical, to those found in static models of migration (see, e.g., Benhabib, 1996).

When a welfare state with egalitarian or insurance motives is in place, the burden of the adjustment falls on native high-skilled/capital owners who have to finance a larger welfare state, both because the income of low-skilled agents drops and because there is a larger fraction of them. These agents, which may previously favor unification, are now worse off and would be willing to provide up to 4% of per-capita consumption over the transition path in "foreign aid" to keep East and West Germany separated. Low-skilled agents are now less affected, but the per-capita losses for the economy are larger, amounting to about 2.5% of consumption over the adjustment path. Hence, the presence of a welfare state not only distorts the path of macroeconomic variables, but also imposes an overall loss of about 1–1.5% of per-capita consumption on the German population over the transition.

The remainder of the paper is organized as follows. Section 2 discusses the dynamic of important macrovariables in Germany; Section 3 outlines our model and discusses its calibration; Section 4 analyzes the quantitative effects of unification; Section 5 repeats the analysis under two different welfare systems; and Section 6 examines the welfare costs of the unification. Section 7 discusses the implications of our results for the recent German experience and concludes.

2. RECENT MACROECONOMIC TRENDS OF THE GERMAN ECONOMY

We begin by providing some facts concerning the German economy in recent years. Figures 1–3 display data for West Germany up to the second quarter of 1990 and for the unified ("Pan") Germany from the first quarter of 1991. The data are from the National Government section of the OECD National Accounts except for population numbers which are from the International Financial Statistics produced by the IMF.

The workforce of West Germany grew steadily through the period 1960–1990 with an annual growth rate of about 0.5% while the population grew faster in the fifties and sixties but then levelled off. With unification the population and the workforce both increased by about 26%.

On impact, unification *increased* real GDP by approximately 14% (from the second quarter of 1990 to the first quarter of 1991) but produced a *drop* in real GDP per-capita of about 10% (see Fig. 1). West Germany

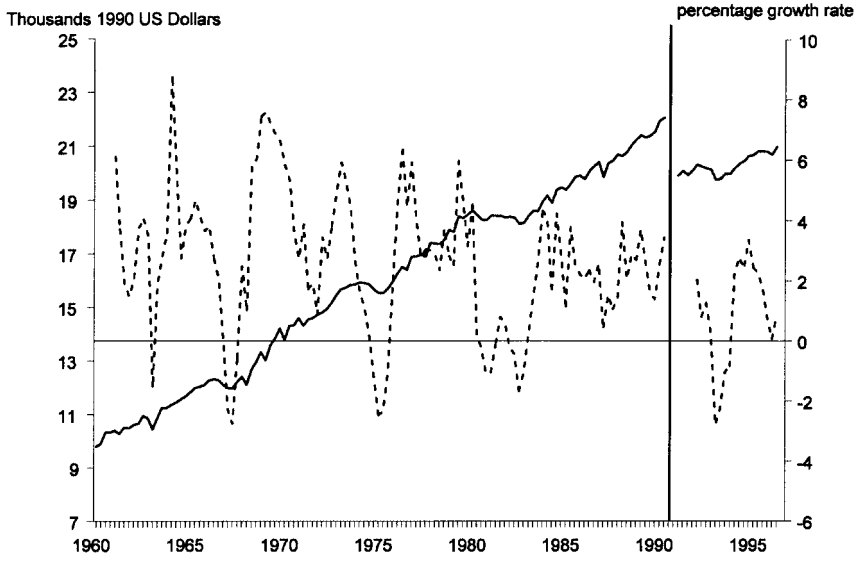

FIG. 1. GDP in Germany (real GDP, West Germany 1960–1990.2, Pan Germany from 1991.1). —, GDP per capita; – – –, annual growth rate.

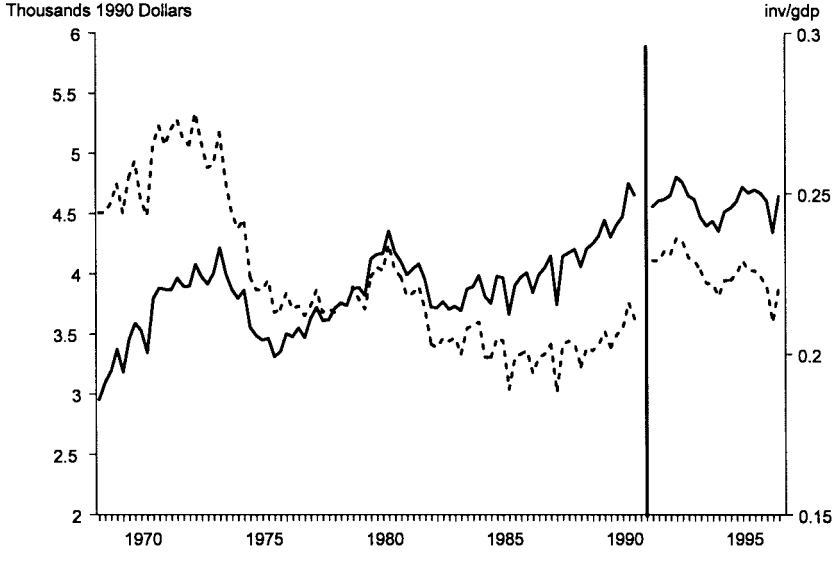

FIG. 2. Fixed investment in Germany (real fixed investment, West Germany 1965–1990.2, Pan Germany from 1991.1). —, investment per capita; – – –, investment/GDP.

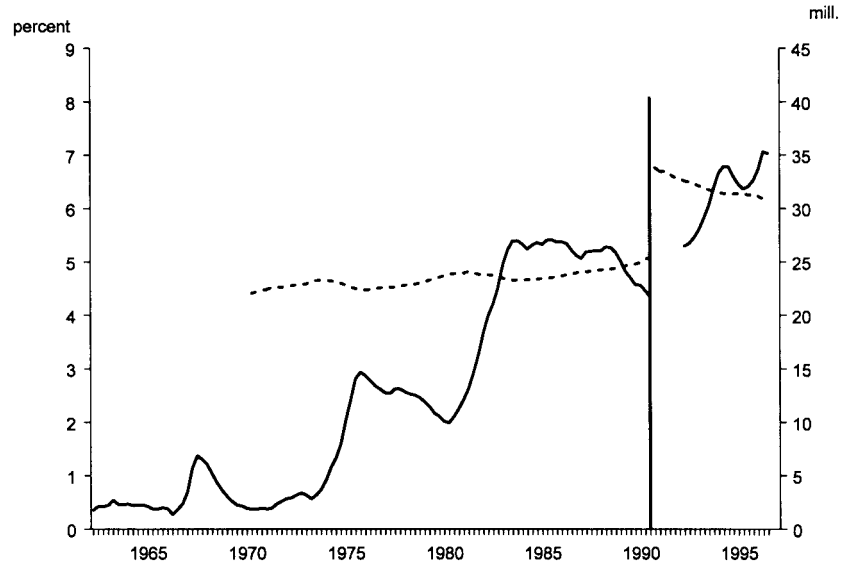

FIG. 3. Employment and the unemployment rate (employment = no. of wage and salary earners, unemployment rate = registered unemployment to the workforce, West Germany 1960–1990.2, Pan Germany from 1991.1). —, unemployment rate; – – –, employment.

ranked third in the world in terms of per-capita GDP in 1989 (after Switzerland and Japan) while in 1997 unified Germany dropped to tenth place. This change in macroeconomic activity is much larger than the one normally observed over the business cycle. From 1991 the average annual growth rate of unified Germany (1%) has been considerably lower than what West Germany achieved during the 1960–1990 period (2.75%) and lower, on average, than the growth rate of other European countries (1.8%). The drop in per-capita income was accompanied by a drop in per-capita consumption of roughly the same amount and the growth rate of consumption over the 1990s mirrors the one of income.

Interestingly, the drop in per-capita GDP is *not* reflected in the level of fixed investments per-capita (see Fig. 2). First, the investment share in GDP of "Pan" Germany in 1991 rose to a level last achieved in 1974. Second, per-capita real fixed investment of unified Germany is roughly the same if not higher than the one of West Germany before unification. The initial investment boom levelled off and the OECD (1998) reports that the growth rate of the gross per-capita capital stock in manufacturing was negative in 1996 and 0.1% in 1997.

Figure 3 plots the employment level, defined as the number of wage and salary earners, and the unemployment rate, defined as registered unem-

ployed to the workforce—the population between 15 and 64 years of age —since 1960. At unification, the percentage increase in employment was larger than the one in either population or the workforce[2] but this tendency was quickly reversed and employment constantly decreased in the period 1991–1997. Associated with the decline in employment was a surge in the unemployment rate. Unemployment in West Germany was very low prior to 1974, but rose dramatically in the 1970s and after the recession of the early 1980s. In the late 1980s, West German unemployment was trending downwards but the unification produced a strong upward trend very different from what was historically experienced. In 1997 the unemployment rate reached an unprecedented 11.5% and levelled off afterwards. The pattern of employment reductions is different across skill categories: agents without formal qualifications (around 40–50% of the West German labor force) suffered the largest surge in unemployment in the 1990s. Nickell (1996) claims that the unemployment ratio between low- and high-skilled workers at the beginning of the 1990s was 4.2 (up from 3.0 in the years before unification) and that over the 1990–1993 period the unemployment rate of low-skilled agents increased by 3 percentage points more than that of the high-skilled agents. In 1995–1996 about 55% of unemployed were without qualification and about 70% had only a minimum level of skills (OECD, 1996). Interestingly, Carlin and Soskice (1997) report that these differential employment reductions were not accompanied by changes in the skilled wage premium and argue that the presence of institutional barriers to wage differentiation may explain this fact.

In sum, unification generated an increase in total activity, a decrease in output (and consumption) per-capita, an increase in the investment share, a small temporary increase in investment and hours worked followed by a decline, and a big surge of unemployment, with the low-skilled component of the population suffering most. The adjustment process seems to be slow and it is unclear how many years it will take unified Germany to catch up with the economic performance of the former West Germany and, indeed, whether this level will ever be attained.

At the regional level the differences between the East and the West deepened after unification. In 1995 the per-capita GDP in the East (excluding Berlin) was 50% of that of the West while the West accounted for approximately 90% of the GDP and 98% of the exports of the "unified" Germany. The GDP of the East dropped by about 35% in the

[2] Because employment figures exclude the self-employed, these differences are exaggerated since a substantial portion of the West German population was self-employed prior to unification while the number of self-employed in East Germany before and immediately after unification was small.

first two years after unification and the average growth rate in the East, after annual rates of about 7–8% for the 1992–1994 period, collapsed to 1.8% in 1996 and has stayed at this level since then. In the first year of unification, industrial production in the East dropped to about one-third of the pre-unification level. In comparison, U.S. industrial production fell by 35% during the Great Depression and in other East European countries the decrease was, on average, 25%. Furthermore, while during the last years of the Berlin Wall, nine million workers were employed in the East, now only 65% of these have jobs. Finally, on the average over the 1991–1996 period, job creation as percentage of labor force has been only 2.8% in the East. This small increase is due to the high average wage costs: in 1996 they were 35% higher than in the West with public services and construction being the only two sectors with comparable cost structure (the differentials are 2 and 12%, respectively). More than 50% of the workers in the East have been retrained since unification but, as argued by Carlin and Soskice (1997, p. 72), a substantial segment of the East German labor force has not yet been able to step into western systems of production.

In 1995, East Germany produced only 60% of what it consumed thanks to the generous and comprehensive "welfare net" that has protected the East since unification. For example, unemployment benefits are between 63 and 68% of terminal wages in the first year and between 53 and 58% in the second year. After two years, unemployment benefits are substituted by welfare payments at the same level obtained after one year of unemployment, with some restrictions applying if the spouse is working. The justification for this massive transfer program was that without such support East Germans would have migrated toward the western part of the country creating political and organizational problems. The result was that West Germans paid higher taxes (a 7.5% solidarity income and corporation surcharge from 1991 to 1997 and a 5.1% increase in the burden of social security contribution (OECD, 1996, p. 76)), accepted higher interest rates, experienced unusually large budget deficits (about 3% of GDP on average over the 1991–1997 period as compared to a 1.5% before unification), and a loss of competitiveness in international markets.

Public transfers to the Eastern landers reached approximately 200 billion marks per year over the 1991–1996 period, an amount which corresponds to 4–5% of the annual West German GDP (about 35% of the local GDP), approximately DM 7500 per-capita or twice the disposable income of Poland. Of these transfers social insurance related payments account for about 45% while investment subsidies account for 12% and direct investment for infrastructures for the rest. Akerlof *et al*. (1991) have estimated that, given the wage hikes of 1990, only 8.2% of the industrial workers could have retained their jobs if production had continued without subsidies with the old technologies. As a consequence of subsidies, trans-

fers, and infrastructure investments, the size of the public sector has roughly doubled between 1991 and 1996.

Given this evidence, the paper asks the following questions: Can we rationalize the economic changes which occurred after the fall of the Berlin wall with a dynamic general equilibrium model? In particular, can we replicate the dynamic adjustments of income per-capita, consumption, investment, and sectorial and total employment following unification? Should we expect unified Germany to go back to the previous standard of living (relative to the trend), once the negative effects of unification are exhausted, or to stay at a permanently lower level? What are the crucial parameters that determine the expected time needed to converge back to the pre-unification conditions? What are the effects of the subsidies that the government pays to insure the income level of Easterners? Who paid for the costs of unification?

3. THE MODEL

The model we use is highly stylized but contains the key ingredients necessary to analyze the issues of interest. First, we model German unification as an exogenous increase in the population. We assume that newcomers acquire the political, legal, and work rights of native residents. This seems a reasonable assumption given that German unification occurred according to article 23 of the West German Constitution which gave the former GDR (German Democratic Republic), or part of it, the right to join the FRD (Federal Republic of Germany) with an equal partner status, provided it accepted the conditions set by the FRD. In practice, the political, legal, and social security system of the FRD was extended with minor changes to the former GDR.

Second, we assume that the newcomers do not bring productive assets with them. To be precise, we assume that the capital stock of the former GDR depreciates quickly after unification. This is based on the observations that between 50 and 70% of the capital stock in place in the former GDR was obsolete or unusable for production in competitive markets (see Siebert, 1991; and Sinn and Sinn, 1992, p. 44) and that the productivity of East German capital at the time of unification was between 16 and 40% of that of West German capital (see Akerlof *et al*., 1991, and Sinn and Sinn, 1992).

Third, we assume that the receiving economy possesses two types of agents that differ in their productivity levels (as in Kydland, 1984, 1995, and Rios-Rull, 1993) and that the increase in the population is due to an increase in the number of low-skilled agents. At first thought this might seem unreasonable since, at the time of unification, the level of human

capital of East German workers, measured either in terms of years of education or the education level of employed workers, was about 40% higher than that of West German workers. Nevertheless, the East German workforce had to be extensively retrained to assimilate their skills to western style of production (see Akerlof *et al*., 1991). Furthermore the "index of rigidity and the lack of adaptability," a measure of the inflexibility of the workforce, was 8.8 for Eastern Germans and 0.13 for Western Germans in 1984 (see Bertocchi and Spagat, 1998). This suggests that although skilled, East German human capital was firm or organization-specific and was lost in the transition.

Fourth, we assume that low-skilled agents are unable to save for future occurrences. The fact that low-income households are restricted from accessing financial markets is well documented in the literature. For example, Campbell and Mankiw (1989) and Mankiw and Zeldes (1991) have estimated that approximately 50% of U.S. households are liquidity constrained. Given the skill features of newcomers, we should expect them to be liquidity constrained as well. However, we go a step further and assume that low-skilled agents (both natives and newcomers) are unable to intertemporally smooth consumption. Although this assumption may look strong, it is the case that many East Germans are currently unable to smooth their consumption stream over time and this gives a scope to the insurance activities of the government. Such a restrictive assumption is common in the literature (e.g., Hall and Mishkin, 1982, and Deaton, 1992), is made here primarily for computational reasons,[3] and affects the composition of the labor supply over the adjustment path, but not the qualitative implications of the model.

Finally, and as a first approximation, we assume a competitive labor market (see Driffill and Miller, 1998, for an alternative setup) and ignore the international repercussions of the unification assuming that the receiving economy is closed.

3.1. *Demographics*. We use a discrete-time version of the Blanchard–Yaari model (see Blanchard, 1985)[4] where individuals have finite planning horizons. At the beginning of each period currently alive individuals face a probability of death, $\pi \geq 0$, which occurs randomly independently of age, date, ethnic background, wealth, and skill-type. Agents that die are replaced by an equal number of newborn agents. Thus, in the absence of unification, there would be no change in the size of the

[3] If we had not assumed this, we would have to keep track of the distribution of asset holdings of newcomers as a state variable. This would unnecessarily complicate the analysis without adding much to the insights.

[4] Among others, Frenkel and Razin (1987) and Cardia (1991) also analyze discrete-time versions of the Blanchard–Yaari model.

population (i.e., the rate of entry into the labor force is equal to the exit rate).

There are two types of agents in the economy, high-skilled and low-skilled. We let $N^s_{a,t}(N^u_{a,t})$ denote the measure of high-skilled (low-skilled) agents of age a at date t, $N^s_t(N^u_t)$ the total measure of high-skilled (low-skilled) agents at date t, $N_{a,t}$ the measure of cohort a at date t, and N_t the measure of all agents in the economy at date t.

We assume that prior to unification, which will be denoted by $t = 0$, the demographic composition of the population is in a stationary state and normalize the measure of the aggregate population to 1. At this date there will be a measure π of newborn agents, a measure $\pi(1 - \pi)$ of agents of one year of age 1, etc. Thus, the size of cohort a is $N_{a,0} = \pi(1 - \pi)^a$.

We assume that at each t a fraction p of the newborn agents is high-skilled and a fraction $1 - p$ is low-skilled. Hence the measure of each type of agents of age a is

$$N^s_{a,0} = p\pi(1 - \pi)^a \tag{1}$$

$$N^u_{a,0} = (1 - p)\pi(1 - \pi)^a \tag{2}$$

and the number of agents of the two types is $N^s_0 = \sum_{a=0}^{\infty} N^s_{a,0} = p$, $N^u_0 = \sum_{a=0}^{\infty} N^u_{a,0} = 1 - p$.

From date $t = 1$ onwards newcomers (East Germans) start entering the country. Let N^e_t denote the inflow of newcomers in period $t \geq 1$. Thus, the aggregate population size is $N_t = N_{t-1} + N^e_t$ $t \geq 1$. All newcomers are assumed to be initially low-skilled. Hence, for $t \geq 1$ the aggregate measures of high-skilled (low-skilled) agents are

$$N^s_t = (1 - \pi)N^s_{t-1} + p\pi N_{t-1} \tag{3}$$

$$N^u_t = (1 - \pi)N^u_{t-1} + (1 - p)\pi N_{t-1} + N^e_t. \tag{4}$$

The first term on the right hand side of (3) is the measure of surviving high-skilled agents, and the second term is the measure of newborn agents that are high-skilled. In (4) the last term is the measure of newcomers that enter in period t.

For reasons that will become clear soon, the age structure of newcomers does not influence the results of our analysis. Thus, we simply assume that all newcomers are "newly born."[5] Given this assumption, cohort sizes at

[5] All the results would be identical if we had assumed that the age distribution of newcomers was identical to that of the natives.

time t are given by

$$N^s_{a,t} = p\pi(1-\pi)^a N_{t-a-1} \tag{5}$$

$$N^u_{a,t} = (1-p)\pi(1-\pi)^a(N_{t-a-1} + N^e_{t-a}), \tag{6}$$

where $N_i = N_0$ for $i \leq 0$ and $N^e_i = 0$ for $i \leq 0$.

Let $\gamma_t = N^s_t/N_t$ denote the share of high-skilled agents at date t. At $t = 0$ we assume that $\gamma_0 = p$. At $t \geq 1$ this share is given by

$$\gamma_t = \frac{N_{t-1}}{N_t}\frac{(1-\pi)N^s_{t-1} + p\pi N_{t-1}}{N_{t-1}} = \frac{1}{g^p_t}((1-\pi)\gamma_{t-1} + p\pi), \tag{7}$$

where $g^p_t = N_t/N_{t-1}$ denotes the gross growth rate of the aggregate population. Notice that, as long as g^p_t is constant, the long-run share of high-skilled agents is equal to p if $\pi > 0$. That is, as long as newcomers die over time and are replaced by the same proportions of high- and low-skilled agents existing in the native population, the long-run share of high-skilled agents will be constant. However, if $\pi = 0$, there is no exit from the labor force and $\gamma_\infty = \gamma_0 + \sum_{t=0}^{\infty} g^p_t$ which depends on g^p_t. Thus, in our setup, the dynamics of the skill composition crucially depends on the rate of entry into and exit from the labor force.

We assume that newcomers arrive gradually in the country. As will be discussed later, this is a short cut to explicitly modeling the fact that the capital stock of the former East Germany depreciated fast but gradually upon unification. We let the inflow of immigrants at date t be $N^e_t = N_0 g^e_t$. Hence $N_t = N_0(1 + \sum_{i=1}^{t} g^e_i)$ and

$$g^p_t = N_t/N_{t-1} = \frac{1 + \sum_{i=1}^{t} g^e_i}{1 + \sum_{i=1}^{t-1} g^e_i}. \tag{8}$$

Finally, we assume that the inflow of newcomers can be represented by a process of the form

$$g^e_t = \psi g^e_{t-1} + \varepsilon^e_t, \tag{9}$$

where only ε^e_1 is positive.

3.2. *Firms*. We assume that there is a large number of identical competitive firms renting factors of production from the households. Production takes place using labor in efficiency units (H^e) and capital (K) and we assume that the production function is Cobb–Douglas with constant returns to scale to these two factors. Hours in efficiency units is a

CES-aggregate of high-skilled hours (H_t^s) and low-skilled hours (H_t^u) and the elasticity of substitution is $1/\rho$. High-skilled hours are more productive than low-skilled hours and $\omega \geq 1$ measures productivity differences.

The maximization problem of the representative firm is

$$\max_{\{H_t^s, H_t^u, K_t\}} \left[\omega \left(H_t^s \right)^{1-\rho} + \left(H_t^u \right)^{1-\rho} \right]^{\frac{\alpha}{1-\rho}} K_t^{1-\alpha} - w_t^s H_t^s - w_t^u H_t^u - r_t K_t, \tag{10}$$

where $H_t^s = \sum_{\alpha=0}^{\infty} N_{a,t}^s h_{a,t}^s$ $H_t^u = \sum_{a=0}^{\infty} N_{a,t}^u h_{a,t}^u$, and $h_{a,t}^s (h_{a,t}^u)$ is the input of labor of high-skilled (low-skilled) workers of age a at date t, $w_t^s (w_t^u)$ the high-skilled (low-skilled) wage rate, r_t the rental rate of capital, and α the labor share of income.

Converting (10) into per-capita terms using the definition of γ_t, we rewrite the problem as

$$\max_{\{h_t^s, h_t^u, k_t\}} \left[\omega \left(\gamma_t h_t^s \right)^{1-\rho} + \left((1-\gamma_t) h_t^u \right)^{1-\rho} \right]^{\frac{\alpha}{1-\rho}} (k_t)^{1-\alpha} - \gamma_t w_t^s h_t^s - (1-\gamma_t) w_t^u h_t^u - r_t k_t,$$

where lower case letters denote per-capita variables, i.e., $k_t = K_t/N_t$, $h_t^s = H_t^s/N_t^s$, and $h_t^u = H_t^u/N_t^u$. Since all markets are competitive, factors are paid by their marginal products and the firms' demand for factors of production satisfy the first-order conditions,

$$r_t = (1-\alpha) y_t / k_t \tag{11}$$

$$w_t^s = \alpha \left[y_t / \left(h_t^e \right)^{1-\rho} \right] \omega \left(\gamma_t h_t^s \right)^{-\rho} \tag{12}$$

$$w_t^u = \alpha \left[y_t / \left(h_t^e \right)^{1-\rho} \right] \left[(1-\gamma_t) h_t^u \right]^{-\rho}, \tag{13}$$

where $h_t^e = [\omega(\gamma_t h_t^s)^{1-\rho} + ((1-\gamma_t) h_t^u)^{1-\rho}]^{1/(1-\rho)}$ denotes "efficiency hours" in per capita terms, and y_t is per capita output. From (12)–(13) we see that for $\rho \geq 0$, the relative skilled wage depends positively on the productivity differential and on the share of low-skilled agents in the economy.

3.3. *Low-skilled agents*. We assume that low-skilled agents own no capital or other financial assets. Since they cannot save and the survival probability is independent of age, all agents of this type alive at any date are identical. Low-skilled agents of age a at date t maximize expected

utility

$$U^u_{a,t} = E_t \sum_{j=0}^{\infty} (\beta(1-\pi))^j \left(\ln c^u_{a+j,t+j} + A \ln\left(l^u_{a+j,t+j}\right)\right) \tag{14}$$

subject to a sequence of budget constraints,

$$c^u_{a,t} \le w^u_t h^u_{a,t}(1-\tau^u_t) = (1-\tau^u_t) y^u_{a,t} \tag{15}$$

and time constraints,

$$l^u_{a,t} + h^u_{a,t} \le 1, \tag{16}$$

where c^u denotes consumption, l^u is leisure, h^u is hours worked, τ^u is the income tax rate, y^u is the unskilled income, β is the subjective discount factor, and $A > 0$ is a share/weight parameter. We have normalized the time endowment to one each period. The solution to the problem is

$$h^u_{a,t} = 1/(1+A), \qquad y^u_{a,t} = [1/(1+A)] \cdot w^u_t, \qquad c^u_{a,t} = (1-\tau^u_t) \cdot y^u_{a,t}. \tag{17}$$

Thus, independent of the cohort, these agents work a constant number of hours and simply consume their after-tax income period-by-period.

3.4. *High-skilled agents*. High-skilled agents are different from low-skilled agents because they are more productive and because they accumulate capital (which they can use to smooth consumption). We assume they are born without any capital holdings. Each period they choose their labor supply, their consumption, and their savings. At the end of each period, they purchase an insurance contract, offered by a large number of competitive insurance companies, which promises them a gross return of $1 + x$ on their end-of-period savings if they are alive at the start of the next period. If the agent dies, her wealth is transferred to the insurance company. Since a fraction π of the agents die each period, it follows from the insurance companies zero profit condition that the gross return $1 + x$ is equal to $1/(1-\pi)$.[6] Surviving high-skilled agents then rent their stock of savings to the firms which use them as working capital in production.

[6] To see this let $\hat{k}^s_{a,t+1}$ denote the end-of-period capital holdings of skilled agents of cohort a in period t. The total receipts of the insurance industry are $R_t = \sum_{a=0}^{\infty} N^s_{a,t} \hat{k}^s_{a,t+1}$. The insurance industry pays out the premiums at the beginning of the next period and total payments are $P_{t+1} = \sum_{a=0}^{\infty} N^s_{a+1,t+1}(1+x)\hat{k}^s_{a,t+1}$ where $N^s_{a+1,t+1} = (1-\pi)N^s_{a,t}$. Thus, the zero profit condition implies that $(1+x) = 1/(1-\pi)$.

We assume that the utility function of high-skilled agents is identical to that of the low-skilled agents. Expected utility of an individual of cohort a at date t is given by

$$U^s_{a,t} = E_0 \sum_{j=0}^{\infty} (\beta(1-\pi))^j \left(\ln c^s_{a+j,t+j} + A \ln\left(1 - h^s_{a+j,t+j}\right)\right) \quad (18)$$

and their flow budget constraint is

$$c^s_{a,t} + x^s_{a,t} \leq \left(w^s_t h^s_{a,t} + r_t k^s_{a,t}\right)\left(1 - \tau^s_t\right). \quad (19)$$

Let high-skilled income be $y^s_{a,t} = w^s_t h^s_{a,t} + r_t k^s_{a,t}$. The capital accumulation equation is

$$k^s_{a+1,t+1} = \frac{1}{1-\pi}\left[(1-\delta)k^s_{a,t} + x^s_{a,t}\right], \quad (20)$$

where $k^s_{0,t} = 0$, x^s_t are investments, τ^s the high-skilled tax rate, and δ the depreciation rate.[7]

We can formulate the maximization problem as

$$v\left(k^s_{a,t}\right) = \max\left(\ln c_{a,t} + A \ln\left(1 - h^s_{a+j,t+j}\right) + E_t \beta(1-\pi) v\left(k^s_{a+1,t+1}\right)\right) \quad (21)$$

subject to (19) and (20) where $v(k^s_{a,t})$ is the value function for an agent that starts the period with a capital holding of $k^s_{a,t}$. The first order conditions for the problem and the envelope condition imply that[8]

$$h^s_{a,t} = 1 - A\frac{c^s_{a,t}}{w^s_t\left(1-\tau^s_t\right)} \quad (22)$$

$$1 = E_t \beta \frac{c^s_{a,t}}{c^s_{a+1,t+1}}\left(1 + \left(1 - \tau^s_{t+1}\right) r_{t+1} - \delta\right). \quad (23)$$

[7] Equation (20) differs from the standard capital accumulation equation in infinite horizon models because the insurance companies pay out premiums only to the agents that are lucky enough not to die.

[8] The first order conditions are given by $1/c^s_{a,t} = \lambda^c_{a,t}$, $A/(1 - h^s_{a,t}) = \lambda^c_{a,t} w^s_t (1 - \tau^s_t)$, $\lambda^c_{a,t} = \frac{1}{1-\pi}\lambda^k_{a,t}$, and $E_t \beta(1-\pi) v'(k^s_{a+1,t+1}) = \lambda^k_{a,t}$, where v' denotes the derivative of the value function, $\lambda^c_{a,t}$ is the multiplier on (19), and $\lambda^k_{a,t}$ denotes the multiplier on (20). The envelope condition is given by $v'(k^s_{a,t}) = \lambda^c_{a,t}(1 - \tau^s_t) r_t + \frac{1-\delta}{1-\pi}\lambda^k_{a,t}$. Combining these gives rise to the Euler equations.

3.5. *The government*. We assume that there is a government whose only aim is to redistribute income across classes of agents via taxes and transfers and it is forced to do this by balancing its budget on a period-by-period basis. Hence the sequence of taxes and transfers must satisfy

$$\sum_{a=0}^{\infty} N_{a,t}^{s} \tau_t^{s} y_{a,t}^{s} + \sum_{a=0}^{\infty} N_{a,t}^{u} \tau_t^{u} y_{a,t}^{u} = 0, \tag{24}$$

where $y_{a,t}^{s}$ and $y_{a,t}^{u}$ are the taxable incomes of the two types of agents. While in practice intertemporal borrowing was used to finance the reconstruction in the first few years of the unification, the conditions of the Maastricht Treaty have forced drastic reductions of government deficits and debt since 1994, de facto imposing a balance budget condition (see Driffill and Miller, 1998). We assume that $\tau_t^{u} = \tau_t^{s} - \mu_t$, so that μ_t is a income tax rebate on low-skilled agents and that τ_t^{s} is endogenously chosen to target certain redistributive policies.

We consider the following two different tax policies:

1. An *egalitarian rule* (ER), where the income tax rate on high-skilled workers is chosen so as to keep the ratio of the average income of the two types of agents constant. That is,

$$(1 - \tau_t^{s}) \sum_{a=0}^{\infty} N_{a,t}^{s} y_{a,t}^{s} / N_t^{s} = \psi (1 - (\tau_t^{s} - \mu_t)) \sum_{a=0}^{\infty} N_{a,t}^{u} y_{a,t}^{u} / N_t^{u}, \tag{25}$$

where ψ is the wedge in the after-tax income of the two types of agents. The left hand side of this expression is the average after-tax income of the high-skilled agents, and the left hand side, apart from ψ, is the average after-tax income of the low-skilled agents.

2. An *insurance rule* (IR), where the government insures the income (consumption) of low-skilled agents from any type of fluctuations; i.e., taxes and transfers are chosen to satisfy

$$(1 - (\tau_t^{s} - \mu_t)) \sum_{a=0}^{\infty} N_{a,t}^{u} y_{a,t}^{u} / N_t^{u} = \bar{y}^{u}, \tag{26}$$

where $\bar{y}^{u}$ is a constant.

The first rule is very common in theoretical studies examining the static effects of migration (see Razin and Sadka, 1995). Egalitarian rules also turn out to be sufficiently popular as redistributive tools in standard models of public finance (see, e.g., Auerbach and Kotlikoff, 1987), to grant them a particular status in our study.

The second rule is of particular interest for two reasons. First, Schrettl (1992) suggests that the distinguishing feature of the East German transition process compared to that of other formerly centrally planned economies was that West Germany provided exactly this type of insurance.[9] Second, the introduction of such a scheme effectively provided saving constrained agents with publicly funded insurance (see, e.g., Padoa-Schioppa, 1987, for the rationale for such a scheme in the context of a European fiscal union).

3.6. *Equilibrium.* In the aggregate the following income composition and resource constraints must hold,

$$y_t = \gamma_t y_t - (1 - \gamma_t) y_t^u \tag{27}$$

$$y_t = \gamma_t c_t^s + (1 - \gamma_t) c_t^u + \gamma_t x_t^s, \tag{28}$$

where aggregated variables are defined as $y_t^s = (\sum_{a=0}^{\infty} N_{a,t}^s y_{a,t}^s)/N_t^s$, $y_t^u = (\sum_{a=0}^{\infty} N_{a,t}^u y_{a,t}^u)/N_t^u$, $c_t^s = (\sum_{a=0}^{\infty} N_{a,t}^s c_{a,t}^s)/N_t^s$, $c_t^u = (\sum_{a=0}^{\infty} N_{a,t}^u c_{a,t}^u)/N_t^u$, $x_t^s = (\sum_{a=0}^{\infty} N_{a,t}^s x_{a,t}^s)/N_t^s$.

We can now define the equilibrium for this economy. We use a standard recursive definition of the equilibrium:

DEFINITION. A recursive competitive equilibrium is a set of functions, $\mathscr{P} = (r, w^s, w^u)$, $\mathscr{T} = (\tau^s, \tau^u, \mu)$, $\mathscr{S} = (c_a^s, h_a^s, x_a^s, k_a^s, h_a^u, c_a^u, k, h^s, h^u)$ such that given the prices $\mathscr{P}$, the taxes $\mathscr{T}$, and the law of motion given by Eq. (9), (i) the skilled households choose $(c_a^s, h_a^s, x_a^s, k_a^s)$ to solve the problem in (21), (ii) the low-skilled households choose (h_a^u, c_a^u) to solve the problem in (14)–(16), (iii) (k, h^s, h^u) solves the firms problem in (10), (iv) the government's budget constraint (24) is satisfied, and (v) all markets clear.

Although the model features two types of agents and high-skilled households differ according to age and capital holdings, it is straightforward to solve for the equilibrium. In the Appendix we provide the steps needed to compute the equilibrium conditions for per-capita variables.

3.7. *Calibration.* We calibrate the model to match annual German data and try to use standard parameter values whenever possible. The selected values and the resulting steady state values for macrovariables are collected in Tables I and II. The depreciation rate is set equal to 10% and the real interest rate to 4%. The parameter α (the labor share of income) is set to 64% (as in Akerlof *et al.*, 1991). All these values are similar to those

[9] Schrettl (1992) also suggests that income transfers to the former East Germany were provided in exchange for the property rights to the capital stock of the former East German government.

TABLE I
Calibrated Parameters

Parameter	Value	Description
β	$1/1.04$	Subjective discount factor
π	0.0, 0.025, 0.04, 0.10	Probability of death
h^u	0.30	Hours worked, low-skilled agents
$A = (1 - h^u)/h^u$	2.33	Preference parameter
γ	0.50	Share of high-skilled agents
α	0.64	Total labor share of income
ρ	0, 0.5	Inverse of elasticity of substitution between high- and low-skilled hours
δ	0.1	Capital depreciation rate
ω	2.0	Productivity difference between high- and low-skilled hours
τ^s	0.00, 0.05	High-skilled marginal tax-rate
ψ	2.63	Income wedge between high- and low-skilled agents in egalitarian rule
μ	Endogenous	Tax rebate for low-skilled agents egalitarian and insurance rules
$\bar{y}$	0.33	Low-skilled income in insurance rule

used by Canova and Marrinan (1998) for West Germany in calibrating a three-country model of the business cycle.

We assume that the population is stationary in the steady state. For moderate values of the income tax parameters these values imply a capital-output ratio of 2.44–2.57, which represents sufficiently well the conditions in West Germany before unification.

For the productivity differential ω Kydland (1984) and Rios-Rull (1993) suggest a value of 2, which seems a reasonable upper bound for the average productivity differences between East and West Germany at the time of unification (see Sinn and Sinn, 1992). We do not know much about the elasticity of substitution between high- and low-skilled workers, $1/\rho$, and different studies have provided estimates for classes of workers which do not fit our classification (see Katz and Murphy, 1992, or Bean and Pissarides, 1991). Therefore, for the benchmark case, we select $\rho = 0$ which matches the fact that the skilled wage premium was approximately constant before the unification and has not shown any substantial change after 1990. For sensitivity we also report results obtained when there is moderate substitutability between the two types of labor ($\rho = 0.5$). The share of workers in West Germany before unification with a secondary education degree or less was about 50% and of these about 20% held no assets. Hence we set $\gamma = 0.50$. Finally, we choose A such that low-skilled agents use 30% of their nonsleeping time on market activities, i.e., $A =$

TABLE II
Steady States Values

Variable	Definition	Value	Description
k/y	$\frac{\beta(1-\alpha)(1-\tau^s)}{1-\beta(1-\delta)}$	$2.57^{a,b}$, $2.443^{c,d}$	Aggregate capital-output ratio
x/y	$\delta k/y$	$0.257^{a,b}$, $0.244^{c,d}$	Aggregate investment-output ratio
c/y	$1-i/y$	$0.743^{a,b}$, $0.756^{c,d}$	Aggregate consumption-output
h^s	$\frac{(1-h^s)\alpha\omega(1-\tau^s)}{As(c^s)} = \frac{\left(\omega(\gamma h^s)^{1-\rho} + ((1-\gamma)h^u)^{1-\rho}\right)}{(\gamma h^s)^{-\rho}}$	$0.254^{a,c}$, $0.254^{b,d}$	Per-capita aggregate skilled hours
h^e	$((h^s)^\rho + (h^u)^\rho)^{\frac{1}{1-\rho}}$	0.40	Per-capita efficiency hours
y		$0.69^{a,b}$, $0.67^{c,d}$	Output level
k	$\frac{k}{y} * y$	$1.771^{a,b}$, $1.63^{c,d}$	Capital stock
$s(c^u) = c^u/y$	$(s(c^u) - \frac{\tau^s}{1-\gamma})((1-\gamma)h^u)^\rho = \frac{\alpha A(1-\tau^s)}{\left(\omega(\gamma h^s)^{1-\rho} + ((1-\gamma)h^u)^{1-\rho}\right)}$	0.475^a, 0.450^b 0.551^c, 0.527^d	Ratio of per-capita unskilled consumption to aggregate output
$s(c^s) = c^s/y$	$1-\gamma s(c^s) - (1-\gamma)s(c^u) - x/y$	1.074^a, 1.036^b 0.960^c, 0.984^d	Ratio of per-capita skilled consumption to aggregate output
c^s		0.70^a, 0.73^b 0.64^c, 0.68^d	High-skilled consumption
c^u		0.33^a, 0.31^b 0.37^c, 0.35^d	Low-skilled consumption

[a] Model with $\rho = 0$ and $\tau^s = 0.00$.
[b] Model with $\rho = 0.5$ and $\tau^s = 0.00$.
[c] Model with $\rho = 0$ and $\tau^s = 0.05$.
[d] Model with $\rho = 0.5$ and $\tau^s = 0.05$.

2.33. These parameters imply, among other things, that the steady state investment-output ratio is about 0.25, that high-skilled hours is 0.25 (36 hours per week), that the capital-labor ratio is 4.37, and that, roughly, low-skilled agents consume about 50% less than high-skilled agents. All of these numbers fit pretty well the features of the West German economy before 1990.[10]

As discussed in Section 2, the population and the workforce of the former East Germany were approximately 26% of those of West Germany at the time of the unification. Examining the effects of a one-time shock of this size may lead to extreme results given that newcomers do not carry productive capital with them. One way to produce more realistic estimates of the adjustment process is to assume that unification happens gradually rather than instantaneously at "unification-day" thereby allowing for gradual scrapping of newcomers' capital. Here we assume that 75% of newcomers' capital scrapped in the first year. In other words, we assume that e_t is an AR(1) process with persistence parameter 0.25.

A crucial parameter we need to calibrate is the probability of death π. This parameter regulates the timing of replacement of existing agents in the economy and determines how long it would take for newcomers to become like natives, in the sense of acquiring the same distribution of skills as natives. Recall that we have assumed that all newcomers are newly born so that the expected time needed to replace them with the same proportion of high- and low-skilled agents existing in the native population is approximately 40–45 years. This is clearly an upper bound which can be sharpened by turning to existing migration evidence for Germany. Felderer (1994) has shown that German speaking migrants toward Germany (primarily of Russian and Polish origin), typically need a generation to have the same skill and income level of the average natives. This suggests that the expected average lifetime of a low-skilled East German joining the federation should be approximately 25 years. Further evidence which can be used to calibrate this parameter comes from reports of the Deutche Bundesbank (1996) which estimated that the retraining period for the East German workforce will be approximately 12–14 years. This estimate appears to be overly optimistic since Soskice (1994) and others have argued that even retrained workers do not usually fit the West German profile of semi-skilled workers, making the expected transition period in the composition of the population probably much longer. Furthermore, retraining efforts have substantially slowed down in the last two years. Overall, this evidence suggests that the East German workforce will be low-skilled for a substantial amount of time after the unification and that the changes in the skill composition brought about by the unification will be persistent.

[10] In particular, the fact that low-skilled agents work more hours than high-skilled agents.

For this reason, we choose for our benchmark $\pi = 0.025$, which implies that the expected labor market participation of agents in the economy is 40 years. Because of the importance of this parameter in determining the expected time needed to converge to the steady state we will also examine three other situations: one where all newcomers are expected to be replaced by newborns in about 10 years ($\pi = 0.10$), one where the inflow of East Germans creates an expected imbalance in the skill composition of agents of about 25 years ($\pi = 0.04$), and one where skill differences are permanent ($\pi = 0.0$). Notice, however, that the adjustments of the skill composition in our model occur because of labor market exits and entries and the share of high-skilled agents among the new agents is constant over time. Thus, the experiments with $\pi = 0.10$ or $\pi = 0.04$ are somewhat unrealistic because they imply that average length of labor market participation is counterfactually low (10 or 25 years).

Finally, we need to calibrate government tax rules. We assume that before unification the high-skilled income tax rate is 5%, a value we believe is reasonable once it is taken into account that the tax rate in our model relates only to the parts of the government budget associated with redistribution. We treat ψ as a parameter and the benchmark value corresponds to the value implied by a 5% income tax rate on high-skilled agents ($\psi = 2.63$). Given other parameters, this implies that low-skilled after-tax income is 38% of the after tax income of high-skilled agents. Finally, we set $\bar{y} = 0.33$, the level of consumption of the low-skilled portion of the native population before unification.

4. THE DYNAMIC EFFECTS OF THE UNIFICATION

We consider first the case where there is no government and, therefore, we set all taxes and redistributive parameters to zero. This step is useful in order to understand how unification would have affected West German macrovariables in isolation from issues arising from redistribution.

4.1. *Short-run adjustments*. The effects on aggregate *per-capita* variables when $\rho = 0$ are reported in Fig. 4A while Fig. 4B shows the effects on disaggregated variables (see Fig. 4.1 for $\pi = 1/25$). Figure 5 presents the behavior of macro- and disaggregated variables when $\rho = 0.5$.

On impact, the response of aggregate variables following a unification disturbance is similar to the one brought about by a sudden disruption of the capital stock. Because the capital-labor ratio (measured in efficiency units) falls at unification, the return to capital increases. This leads to an increase in the investment share of output of about 1.8% (to about 26.8%)

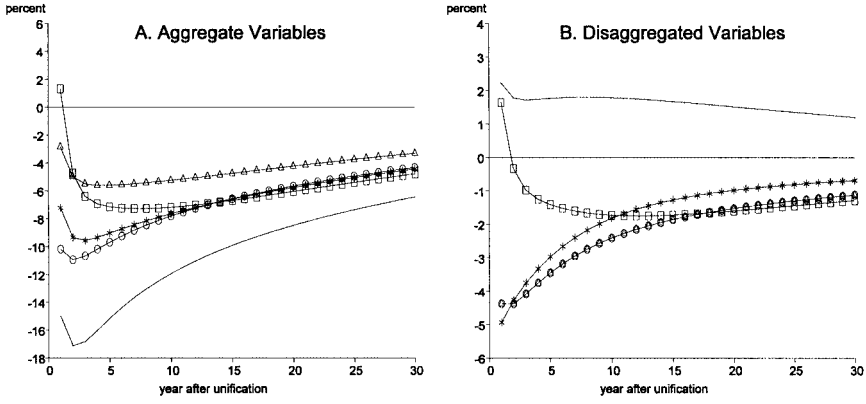

FIG. 4. Dynamics in the baseline model (percentage deviations from initial steady state in years following the unification). (A) —, capital stock; ∗ ∗, output; ⊖ ⊖, consumption; ⊟ ⊟, investment; ▵ ▵, efficiency hours. (B) —, skilled income; ∗ ∗, skilled consumption; ⊖ ⊖, unskilled consumption; ⊟ ⊟, skilled hours; ▵ ▵, wage.

and to an increase in investment per-capita of 2%.[11] The decline in output per-capita (7%) is smaller than the initial drop in the capital-labor ratio (about 15%) because high-skilled agents work harder to reconstruct the per-capita capital stock. As a consequence total hours increase (about 8%) but efficiency hours decline (by about 2%) because more low-skilled

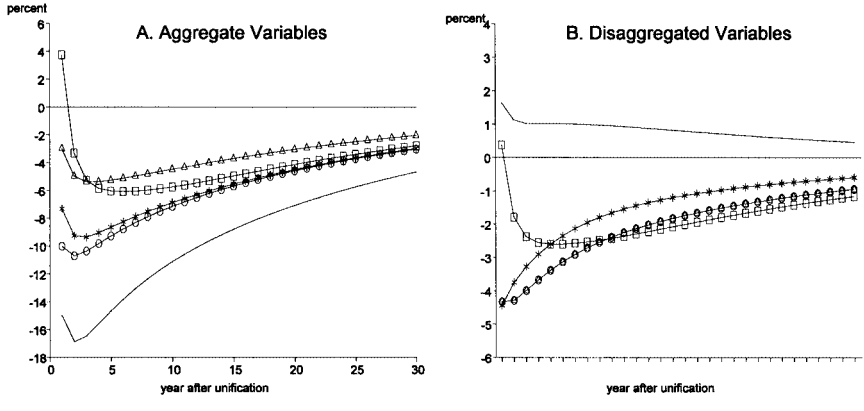

FIG. 4.1. Dynamics when $\pi = 1/25$ (percentage deviations from initial steady state in years following the unification). (A) —, capital stock; ∗ ∗, output; ⊖ ⊖, consumption; ⊟ ⊟, investment; ▵ ▵, efficiency hours. (B) —, skilled income; ∗ ∗, skilled consumption; ⊖ ⊖, unskilled consumption; ⊟ ⊟, skilled hours; ▵ ▵, wage.

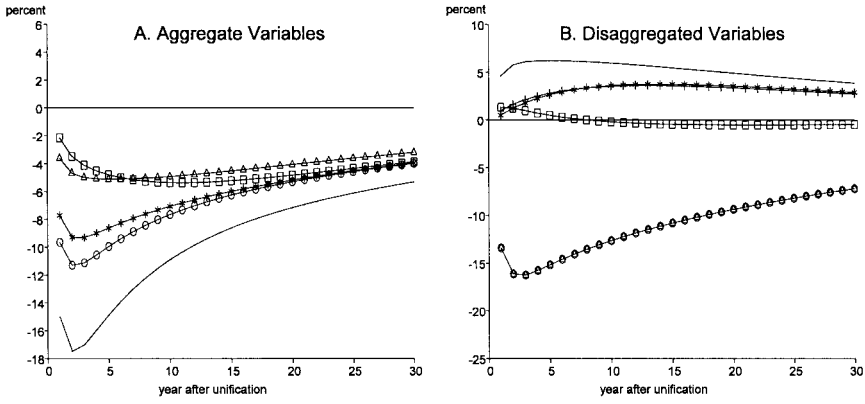

FIG. 5. Dynamics with imperfect substitutability ($\rho = 0.5$, percentage deviations from initial steady state in years following the unification). (A) —, capital stock; ∗ ∗, output; ⊖ ⊖, consumption; ⊟ ⊟, investment; ▵ ▵, efficiency hours. (B) —, skilled income; ∗ ∗, skilled consumption; ⊖ ⊖, unskilled consumption; ⊟ ⊟, skilled hours; ▵ ▵, unskilled wage; ∓ ∓, skilled wage.

agents are employed. Note that in Germany output per-capita declined by 10%, investments were roughly unchanged, and employment increased by 15% in the first year after unification.

The model predicts "undershooting" output dynamics: after the initial drop, output per-capita keeps on decreasing for about 3 years before picking up. Its growth rate, on the other hand, decreases temporarily for about 4 years and then jumps above the previous steady state level. This phenomenon is consistent with the German data presented in Fig. 1. The decline in aggregate consumption is larger than the one in income (on impact about 10%), because of the need to channel resources to increase investments but the turn-around is faster and its growth rate picks up again after 2 years.

With the unification, the wage per efficiency unit decreases and the interest rate increases since the capital-labor ratio falls. This differential behavior of the marginal product of the two factors of production produces a redistribution of income across classes of agents. Low-skilled agents experience a drop in income and consumption while high-skilled agents,

[11] The effect on the investment share is independent of the assumption that unification occurs gradually while the effect on investment per-capita does depend on this assumption. The reason is that with gradual unification, the investment response is stronger because today's changes signal future changes.

who own the capital stock, enjoy an increase in income. However, their consumption declines because they devote resources to increase investments.

Akerlof *et al*. (1991) estimated that if 4% of the East German labor force would migrate to the West, wages would have been be depressed on average by 3.15%. Since 4% of the East German labor force corresponds roughly to a 1% temporary flow of migrant we find, contrary to their calculations, that the maximum drop caused by this inflow on low-skilled wages in the receiving economy is only 0.5%.

Over the adjustment path, high-skilled workers experience a strong income effect, since they are now a smaller fraction of the population and own more capital per head. This makes their income persistently higher and their hours lower over the medium term, with low-skilled labor substituting for high-skilled labor in production. After that the initial boom investment per-capita declines and remains persistently below the original steady state (by about 4%). Recall that this is qualitatively consistent with Germany's data from the middle of the 1990s: after the initial increase investments slacked and turned negative in 1996 and then essentially zero in 1997.

In conclusion, the model predicts that unification would have produced an instantaneous increase in aggregate investments, in output and investment to output ratio, a persistent decline of per-capita consumption and output, and a temporary increase in hours worked by the more productive side of the economy followed by a decline. These effects are qualitatively similar to those observed in Germany but the recessionary consequences are smaller than in the data. The model also predicts an instantaneous increase in investment per-capita which is slightly too large, while the subsequent decline is consistent with actual German data.

The dynamics obtained when the two types of labor are imperfectly substitutable in production are similar. The main difference concerns investments which immediately drop by 2% and keep on declining for about 10–12 years. To see what accounts for the difference in the behavior of investment in the short run it is instructive to examine disaggregated variables. With imperfect substitution there is a wedge between high- and low-skilled wages: an inflow of low-skilled agents increases the relative wage of high-skilled workers unless there is a corresponding large increase in their labor supply. For the parametrization we use, high-skilled labor supply increases but by much less than in the perfectly substitutable case, so that high-skilled wage increases both on impact and over the adjustment path. This effect is substantial and the adjustments induced by relative wage changes dominate in magnitude those induced by variations in the price of capital and labor. This implies that only low-skilled natives face

the burden of labor market competition from newcomers while high-skilled natives benefit both because they own more capital per head and because their wage rate increases. Hence, while both high-skilled consumption and income increase, the decline in low-skilled consumption and income is much more severe than in the case analyzed in Fig. 4. Finally, because the increase in high-skilled hours is small the economy reconstructs the capital stock at a much slower pace wiping out the investment boom observed when the two types of labor are perfect substitutes.

Overall, although the time path of macroeconomic aggregates appears to match more closely those of Germany after unification, it is also the case that in the model the skilled wage premium increases with unification to a maximum of about 3% above the original steady state 15 years after the disturbance. Since in Germany, the wage premium between high-skilled and low-skilled workers was roughly constant after unification (see Carlin and Soskice, 1997), we find the results obtained where the two types of labor are perfect substitutes are more appealing.

4.2. *Long-run effects*. As mentioned, the time needed to absorb the initial unification disturbance in the model depends on the pace at which low-skilled newcomers are substituted by the same proportion of high- and low-skilled agents existing in the native population. The results we have presented in Figs. 4 and 5 assume that on average it will take 40 years for the skill composition of the population to get back to the pre-unification level. Since there is considerable uncertainty regarding the pace at which this substitution actually occurs in Germany—in the last few years the retraining efforts of East Germans have been considerably slowed down because of budgetary constraints (see OECD, 1998)—it is instructive to examine the state of the economy in the long run (25 years after the shock) under different assumptions about π.

In the first column of Table III we report variations relative to the original steady state when none of the agents have been replaced, $\pi = 0$, so that the share of high-skilled agents in the economy 25 years after the shock is roughly 40%. In the second column, we report variations when $\pi = 0.025$, in which case the share of high-skilled agents is equal to 44.5%; in the third column we consider the case $\pi = 0.04$, so that the share of high-skilled agents is 46.2%; in the fourth column we have results for $\pi = 0.10$, in which case the share of high-skilled agents is 49.2%. The first panel refers to the case $\rho = 0$ and the second to $\rho = 0.5$.

The magnitudes of the long-run aggregate effects are large. When we assume that $\pi = 0$, our model predicts that output-per-capita, the capital stock, and effective hours will still be about 7% below the previous steady

TABLE III
"Long-Run Changes": Percentage Deviations from Initial Steady State
25 Years after Unification. No Taxes

	$\rho = 0$				$\rho = 0.5$			
	$\pi = 0.00$	$\pi = 0.025$	$\pi = 0.04$	$\pi = 0.10$	$\pi = 0.0$	$\pi = 0.025$	$\pi = 0.04$	$\pi = 0.10$
y	−6.71	−5.04	−4.08	−1.57	−6.71	−4.51	−3.49	−1.24
h^e	−6.62	−3.75	−2.54	−0.24	−6.59	−3.61	−2.43	−0.30
h^t	0.58	0.24	0.21	0.27	1.14	0.64	0.49	0.27
x	−6.54	−5.39	−4.08	−0.34	−6.50	−4.34	−3.09	−0.21
k	−6.87	−7.36	−6.84	−3.94	−6.91	−6.11	−5.39	−2.91
c	−6.77	−4.93	−4.09	−2.00	−6.78	−4.56	−3.63	−1.59
y^s	5.00	1.35	0.37	−0.51	9.44	4.37	2.67	0.13
h^s	−2.31	−1.44	−0.90	0.30	−0.99	−0.52	−0.25	0.30
c^s	0.70	−0.81	−1.24	−1.43	7.42	3.23	1.74	−0.51
y^u	−0.09	−1.30	−1.55	−1.33	−13.4	−8.20	−6.09	−1.92
c^u	−0.09	−1.30	−1.55	−1.33	−13.4	−8.20	−6.09	−1.92

state, and that high-skilled income and consumption will be above the steady state by 5.0 and 0.7%, respectively. If $\pi = 0.025$ the drop in efficiency hours is halved while the effects on aggregate consumption and aggregate income are only slightly smaller. However, in this case there is a significant change in the level of consumption and income of the high-skilled agents. They are now below the previous steady state indicating that the positive effect due to high returns to capital has been completely absorbed by the economy after 25 years. Even in two more optimistic cases macroeconomic adjustments are far from being complete. For example, when $\pi = 0.10$, the capital stock and aggregate consumption are still below their previous steady state by 4 and 2%, respectively.

When $\rho = 0.5$ the results are similar even though it appears that as π increases the deviation of aggregate values from the original steady state decreases. For disaggregated variables this is not the case. Given the wage premium created by the inflow of newcomers low-skilled consumption and income are typically below steady state by a large amount and high-skilled income is above the steady state even when $\pi = 0.10$.

Since one might link π to the retraining efforts of the German government the results of Table III suggest two important conclusions. First, regardless of the investment made in retraining, the adjustments are likely to be long. Even when the skill composition of the economy has returned to its pre-unification level, long lasting effects, due to changes in the capital-labor ratio, are evident. Second, it may be very costly to retard the retraining effort. Even in the most optimistic scenario, income and capital

per-capita will still be substantially below their steady state values 25 years after unification and the effects of the disturbance will still imbalance the distribution of income of unified Germany at that data.

It has been estimated (see Sinn and Sinn, 1992) that it would take over a trillion DM of private investment to reconstruct the capital stock per-worker in the East at the 1989 West German level. Assuming that the 1989 level was the pre-unification steady state, this implies that over 100 billion DM a year for 10 years are needed for East Germany to catch up, with mean share of investment to GDP between 80 and 130% (in West Germany in 1990 the mean share was, depending on the calculation, between 13 and 26%).

The outcome of this experiment in our model though depends on the definition of labor. In terms of labor unadjusted for the productivity of the workers, the required change in the capital stock needed to keep the capital-labor ratio unchanged is approximately 50% of the initial GDP before unification. Thus, if this was to be financed within East Germany and achieved within 10 years, it would necessitate to an investment share of approximately 57%, as compared with a steady-state share of roughly 25%. In terms of labor in efficiency units the numbers are smaller because the change in total effective hours is lower than the change in total unadjusted hours. In this case, the investment share should increase to approximately 45%.

5. UNIFICATION AND THE WELFARE STATE

Next, we examine whether the addition of a welfare state changes the short dynamics of the macrovariables we have previously described. For reason of space we report results only for $\rho = 0$. Higher values of ρ imply larger and more persistent tax effects.

5.1. *Egalitarian tax rule*. In a model with a welfare state, the capital-labor ratio changes over the adjustment path not only because hours change but also because the tax rate must increase to balance the budget. This leads to a larger drop in aggregate activity in per-capita terms both on impact (about 7.6% compared to about 6.8% in the previous case) and over the entire adjustment path (see Fig. 6). Similarly, hours in efficiency units drop more and stay consistently below the path generated in the benchmark case. The most relevant changes however occur in aggregate consumption and investments: the latter drastically falls on impact (about 3%) and this fall is compensated by a smaller drop in consumption.

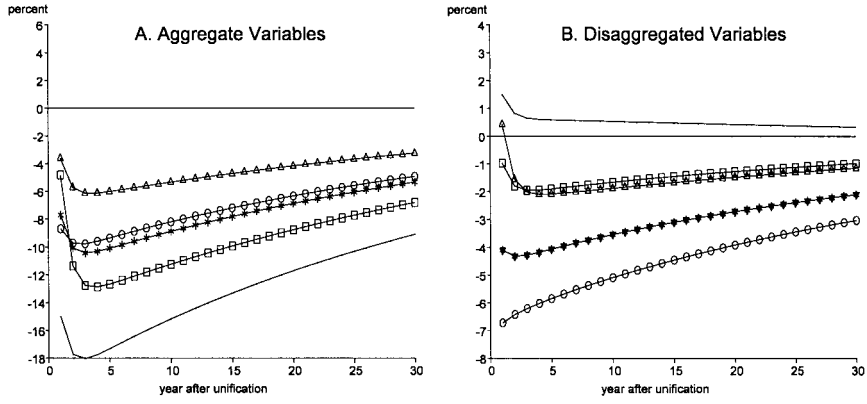

FIG. 6. Dynamics with egalitarian taxes (percentage deviations from initial steady state in years following the unification). (A) —, capital stock; ∗ ∗, output; ⊖ ⊖, consumption, ⊟ ⊟, investment; △ △, efficiency hours. (B) —, skilled income; ∗ ∗, unskilled income; ⊖ ⊖, skilled consumption; ⊟ ⊟, unskilled consumption; △ △, skilled hours; ▽ ▽, wage.

The impulse responses presented in Fig. 6B indicate that these changes relative to the baseline case occur because the marginal tax rate on high-skilled agents increases following the increase in their before-tax income. This increase in marginal taxes discourages investments and produces the observed negative effect on hours in efficiency units, wage, and production per-capita. It also leads to a prolonged adjustment process with the capital stock significantly below both the steady state value and the value obtained without a welfare state 25 years after the disturbance (almost 12% below steady state as compared to 6.8%).

The higher marginal tax rate on high-skilled agents also discourages them from working harder to rebuild the capital stock while the increase in income resulting from higher return to capital is more than compensated for by the increase in the tax burden. Hence high-skilled consumption declines on impact more—down 7% from its steady state value, as compared to a 5% decrease in the case without the welfare state—and stays persistently below its steady state value. Low-skilled consumption drops instantaneously, as it was the case without the welfare state, but the magnitude of the drop is much smaller (1% compared to 15%). Also, high-skilled consumption drops significantly more than low-skilled consumption over the adjustment path because a welfare state with these characteristics penalizes agents who are richer with unification. With a marginal tax rate adjusted to keep a constant distribution of income, high-skilled agents now bear the majority of the adjustment costs associated with the unification.

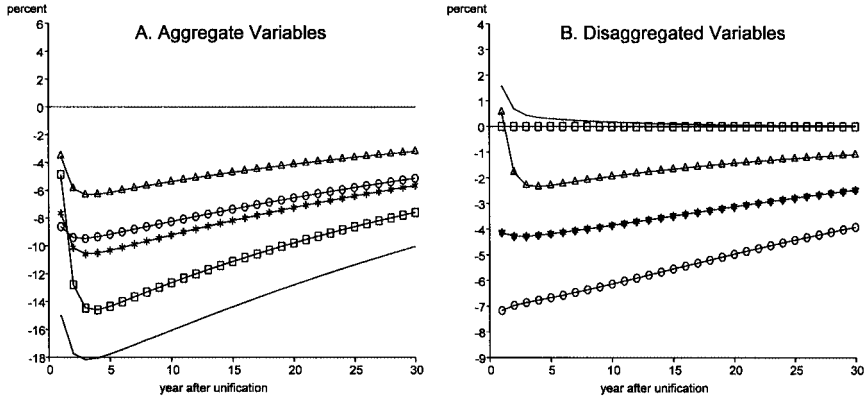

FIG. 7. Dynamics with insurance taxes (percentage deviations from initial steady state in years following the unification). (A) —, capital stock; ∗ ∗, output; ⊖ ⊖, consumption; ⊟ ⊟, investment; △ △, efficiency hours. (B) —, skilled income; ∗ ∗, unskilled income; ⊖ ⊖, skilled consumption; ⊟ ⊟, unskilled consumption; △ △, skilled hours; ▽ ▽, wage.

In the long run, the presence of a welfare state has significant depressive effects on macroeconomic activity. After 25 years, output is about 2% below and the capital stock 4% below the level which would be obtained without a welfare state. This implies that a redistributive welfare state cuts the growth rates of income by 1% on average relative to the potential of the economy.

In sum, this redistribution scheme has important side effects when unification takes place under the conditions we have described. When the government tries to maintain the income distribution constant over the adjustment path, the "size" of the welfare system increases and high-skilled agents, which are a smaller fraction of the population, must contribute a larger percentage of government outlays. Because they are taxed more heavily they do not take advantage of investment opportunities generating a reduction of per-capita income (and of its growth rate) that exceeds that observed in the case without redistribution.

5.2. *Insurance tax rule.* The quantitative differences between this scenario and the egalitarian case are small (see Fig. 7). As with the previous tax rule, the marginal tax rate must increase with unification so as to keep the level of income of low-skilled agents constant and this leads to changes in the capital-labor ratio that reinforce the negative effects on aggregate activity obtained in the benchmark case. Quantitatively, the effects are slightly larger than in the case of egalitarian taxes: the disturbance now leads to a significantly larger drop of investments three years after the disturbance (14% as compared to 12% in the case of egalitarian taxes),

suggesting that the associated tax changes are larger under this rule. This larger drop in investments has negligible effects on other aggregate macroeconomic variables: the changes in output per-capita, consumption, and efficiency hours are fairly similar to those obtained with egalitarian taxes.

At the disaggregated level there are interesting patterns. First, since wages fall more in the short run, taxes need to be increased more relative to the egalitarian case because high-skilled income is adversely affected by the drop in wages. Second, competition from low-skilled newcomers decreases pre-transfer low-skilled income but their consumption is unchanged. With egalitarian taxes low-skilled consumption declines over the adjustment path so that these agents are better off with this tax rule. Third, since high-skilled agents now bear higher costs we observe larger short run decreases in investment per-capita, consumption, and high-skilled hours. Fourth, the long-run effects on high-skilled agents are stronger: for example, after 25 years their consumption is 4.5% below the steady state as compared to a 3.5% in the case of egalitarian taxes.

To summarize, the temporary but persistent increase in the number of low-skilled agents leads to a substantial increase in the size of the welfare state. In the case of egalitarian taxes the burden of a larger welfare state is shared by the two types of agents in the population. In the case of insurance taxes the increase in the welfare state is financed by high-skilled agents who totally bear the costs of unification. In both cases the presence of a welfare state reinforces the depressive effects on output per-capita and efficiency hours produced by the unification because higher tax rates prevent high-skilled/capital owners from taking advantage of the investment opportunities generated by the temporary drop in the capital-labor ratio. These depressive effects translate into a deep and prolonged recession, a lower growth rate of output per-capita, and a slower transition toward the steady state. With insurance taxes these effects are larger because to maintain low-skilled consumption constant the government taxes more heavily the productive sector of the economy further distorting the incentive to save and invest.

Which sectors of the society benefit from the presence of a redistributive rule when unification takes place? We quantitatively address this problem in the next section.

6. A WELFARE ANALYSIS

The model predicts that with unification there is considerable redistribution of income across different classes of agents, even in the absence of a welfare state. Hence we would like to measure the costs and gains over the

adjustment path and assess who is benefitting and by how much. Since high- and low-skilled agents are affected differently by the unification process, we will distinguish the welfare of these two types of agents in the exercise.

We base our welfare analysis upon the computation of "compensated" consumption levels for an aggregate of the cohorts for each type of agent. This is not restrictive for low-skilled agents since they are identical, irrespective of the cohort to which they belong. For high-skilled agents this is more critical because they differ in their capital holdings and, thus, in their choices of labor supply, consumption, and saving. However, our solution procedure does not allow us to recover the variables of the economy at the cohort level. Hence, we follow Calvo and Obstfeld (1988) and base the computation upon the aggregate per-capita consumption of each of the two types of agents in the economy.

We let $c_t^s (c_t^u)$ be the per-capita consumption of the high-skilled (low-skilled) agents along the transition path, and h_t^s per-capita hours worked by the high-skilled along this path (recall also that low-skilled hours are constant). Define $\hat{c}_0^u = \sum_{a=0}^{\infty} N_{a,0}^u c_{a,0}^u / N_0^u$ as the pre-unification steady state level of low-skilled consumption and $\hat{c}_0^s = \sum_{a=0}^{\infty} N_{a,0}^s c_{a,0}^s / N_0^s$ and $\hat{h}_0^s = \sum_{a=0}^{\infty} N_{a,0}^s h_{a,0}^s / N_0^s$ as the pre-unification steady-state levels of per-capita high-skilled consumption and hours.

Following Lucas (1987), we compute "compensated" consumption levels $\tilde{c}_0^s$ and $\tilde{c}_0^s$ that satisfy the conditions

$$\sum_{t=0}^{\infty} (\beta(1-\pi))^t \left[\ln \tilde{c}_0^u + A \ln\left(1 - \hat{h}_0^u\right)\right] = \sum_{t=0}^{\infty} (\beta(1-\pi))^t \times \left[\ln c_t^u + A \ln\left(1 - h_t^u\right)\right] \tag{29}$$

$$\sum_{t=0}^{\infty} (\beta(1-\pi))^t \left[\ln \tilde{c}_0^s + A \ln\left(1 - \hat{h}_0^s\right)\right] = \sum_{t=0}^{\infty} (\beta(1-\pi))^t \times \left[\ln c_t^s + A \ln\left(1 - h_t^s\right)\right]. \tag{30}$$

Thus, $\tilde{c}_0^u$ is the level of low-skilled consumption such that the present value of the utility stream generated by consuming $\tilde{c}_0^u$ and working $\hat{h}_0^u$ hours every period gives low-skilled agents the same utility level as the present value of the utility stream of the equilibrium low-skilled consumption and hours worked along the transition path following the unification. $\tilde{c}_0^s$ is defined similarly for the high-skilled agents. If $\tilde{c}_0^s > \hat{c}_0^s$ $(\tilde{c}_0^u > \hat{c}_0^u)$ the

unification is welfare improving for the high-skilled (low-skilled) agents. Using these, we also compute the change in "aggregate" consumption from comparing $\tilde{c}_0^a$ with $\hat{c}_0^a$ where $\tilde{c}_0^a \equiv \gamma_0 \tilde{c}_0^s + (1 - \gamma_0)\tilde{c}_0^u$, $\hat{c}_0^a \equiv \gamma_0 \hat{c}_0^s + (1 - \gamma_0)\hat{c}_0^u$. Notice that we focus upon the natives in these computations.

In Table IV we present the results of our investigation. For each of the three regimes we analyzed we compute the percentage changes in consumption by the high-skilled and the low-skilled portions of the population and in per-capita terms for the economy as a whole over the adjustment path when we vary the probability of death $\pi = 0.04; 0.025$, the productivity differential among agents $\gamma = 2.0; 1.0$ and the elasticity of substitution between high- and low-skilled workers in production $\rho = 0.0; 0.5$.

Consider first the case of no taxes. Then high-skilled agents benefit regardless of the probability of death or the productivity differential when the two types of labor are an imperfect substitute. Gains are larger the smaller the productivity differences and the smaller the probability of death. When the two types of labor are perfect substitutes in production, high-skilled agents lose from unification and losses are positively related to the probability of death and to productivity differentials. For low-skilled agents the unification is always a bad outcome. Depending on the parameter values they lose between 3 and 11.5% of consumption on the transition path. Given that there is a larger fraction of these agents in the economy, per-capita consumption losses amount to about 1.5–2.5% and they are larger when the probability of death is larger, the productivity differential and the elasticity of substitution smaller.

TABLE IV
Welfare Costs of Unification

Parameter values	No taxes			Egalitarian taxes			Insurance taxes		
	Δc^s	Δc^u	Δc^a	Δc^s	Δc^u	Δc^a	Δc^s	Δc^u	Δc^a
$\pi = 0.04$ $\omega = 2.0$ $\rho = 0$	−1.53	−2.92	−1.98	−3.68	−2.05	−3.09	−4.81	0	−3.06
$\pi = 0.04$ $\omega = 2.0$ $\rho = 0.5$	1.81	−11.3	−2.14	−3.13	−2.38	−2.87	−4.35	0	−2.84
$\pi = 0.04$ $\omega = 1.0$ $\rho = 0$	−1.02	−3.76	−2.33	−4.21	−1.92	−3.04	−6.14	0	−2.99
$\pi = 0.04$ $\omega = 1.0$ $\rho = 0.5$	3.39	−9.69	−2.55	−3.26	−2.17	−2.73	−5.23	0	−2.67
$\pi = 0.025$ $\omega = 2.0$ $\rho = 0$	−1.12	−2.44	−1.54	−3.57	−1.43	−2.79	−4.40	0	−2.80
$\pi = 0.025$ $\omega = 2.0$ $\rho = 0.5$	2.70	−11.54	−1.61	−2.99	−1.99	−2.64	−4.07	0	−2.65
$\pi = 0.025$ $\omega = 1.0$ $\rho = 0$	−0.55	−3.20	−1.82	−4.31	−1.16	−2.69	−5.57	0	−2.71
$\pi = 0.025$ $\omega = 1.0$ $\rho = 0.5$	4.61	−9.76	−1.91	−3.17	−1.73	−2.47	−4.85	0	−2.48

Note. π is the death probability, ω the productivity differential, and ρ the inverse of the elasticity of substitution. $\Delta c^s = 100((\tilde{c}_0^s - \hat{c}_0^s)/\hat{c}_0^s)$ is the compensated consumption variation for high-skilled agents, $\Delta c^u = 100((\tilde{c}_0^u - \hat{c}_0^u)/\hat{c}_0^u)$ is the compensated consumption variation for low-skilled agents, and $\Delta c^a = 100((\tilde{c}_0^{ag} - \hat{c}_0^{ag})/\hat{c}_0^{ag})$ is the compensated consumption variation for the average agent in the economy where $\tilde{c}_0^{ag} = \gamma_0 \tilde{c}_0^s + (1 - \gamma_0)\tilde{c}_0^u$.

With egalitarian taxes both types of agents are worse off with unification regardless of the elasticity of substitution. In per-capita terms losses amount to 2.5–3.0% of consumption. Low-skilled agents are better off relative to the case of no taxes with losses never exceeding 2.4% of consumption, while high-skilled agents would now be willing to provide 3–4% of consumption in "foreign aid" to avoid unification to occur. These agents are worse off when the probability of death is larger, when the productivity differentials are smaller, and when no wage premium is created with the unification.

Finally, with insurance taxes, low-skilled consumption is constant, but the losses for high-skilled agents are so large (4–6% of consumption) that in per-capita terms the economy still expects to lose 2.5–3.0% with unification. With this rule, losses are decreasing in π, increasing in ω, and decreasing in ρ.

In conclusion, when we use the compensated change in per-capita consumption to synthetically compare welfare across different scenarios we find that the introduction of a welfare state significantly penalizes the average agent in the economy, tilting the costs of unification away from low-skilled agents toward capital owners.

7. LESSONS FOR THE GERMAN EXPERIENCE AND CONCLUSIONS

Our exercise has provided us with some indications on how to interpret the recent macroeconomic developments in the German economy after the fall of the Berlin Wall.

We modelled the unification of the two sides of Germany as an exogenous increase in the low-skilled portion of the population, the portion that holds no capital. Absent any government redistribution scheme, this combination of circumstances has effects very similar to those brought about by a sudden disruption of the per-capita capital stock of the receiving economy: in the short run, entrepreneurs will invest to rebuild the capital stock and high-skilled agents will work harder to intertemporally take advantage of the investment opportunities. Over the adjustment path both capital and output per-capita will be lower and will slowly converge to their steady state levels from below. Total hours increase but hours in efficiency units will drop since low-skilled workers, which are now a larger proportion of the labor force, work less than high-skilled workers. With the chosen parametrization the adjustment takes a long time and the redistribution of income during the transition is substantial. Hence, our model predicts that German unification would have generated a boom in investment per-capita, a temporary decrease in the growth rate of output,

a persistent redistribution of income to the entrepreneur sector, and a prolonged decline in per-capita income. Therefore, capital owners (the rich westerners) would have benefitted from the unification and the drop in the world ranking of per-capita income experienced by Germany after unification should have been expected as a result of the decline in the capital-labor ratio.

The choice of the government to engage in generous redistribution schemes in favor of low-skilled agents should not come as a surprise since the persistent redistribution in favor of the entrepreneur sector would have been unsustainable or very difficult politically. What are the consequences of this action? The redistributive burden on high-skilled/capital owners may have significantly exasperated the recessionary effects and produced worse long-run conditions since the increased tax burden discouraged private investments and decreased the net contribution of these agents to the welfare state, just at a time when welfare outlays were about to increase. Hence, as the tax burden began to bite, investment and output per-capita declined relative to the no redistribution case, both instantaneously and over the adjustment path. In conclusion, the decline in the standards of living of Germany is due to a combination of constrains on investment opportunities and redistribution which tilted the economy into a "vicious" path.

Although the model is successful in qualitatively reproducing the time path of macroeconomic variables after unification, several qualifications are in order. We have assumed that the government finance transfers on a period-by-period basis, while in Germany transfers are partially financed by borrowing. If the economy is Ricardian or the horizon of repayment of the government debt is short (because of Maastricht rules), our setup mimics well the expected effects that would occur even when borrowing is present.[12] Second, we have neglected the possibility that Easterners may be endowed with some savings at the time of unification. This feature can be added to the model without changing the substance of the results. This is because without redistribution low-skilled income declines, so it is conceivable that newcomers will run down their assets to increase current consumption along the adjustment path. Therefore, the addition of a saving endowment will have no effects on capital accumulation or output per-capita. If easterners' savings are canalized toward investment, rather than consumption, both low-skilled and high-skilled consumption will decline less and there may be a smaller effect on output. In other words, if

[12] If some borrowing is allowed, it is likely that the government will try to smooth tax rates over the transition period, implying a lower burden on the skilled workers on the path to the new steady state (see Driffill and Miller, 1998). In a Ricardian economy like ours steady states are unchanged by borrowing decisions of the government.

East Germans could be convinced to be more patient in their consumption needs, the whole economy could be better off, both instantaneously and along the adjustment path. However, since consumption desires have been constrained for so many years, this possibility was hardly an option at the time of unification.

Third, we have disregarded the fact that the reconstruction in the East was partially financed with foreign capital. After unification, there was a substantial change in German's external payments. The current account balance of West Germany was in a surplus for almost all the 1980s, averaging about 2.1% of West German GDP. After unification the current account went into a deficit of about 1% of the unified German GDP and it has stayed negative ever since. Would any of our results change if we allow foreigners to finance the reconstruction of the per-capita capital in unified Germany? To answer this question we treat unified Germany as a small open economy relative to the rest of the world. Results obtained for this setup (see Canova and Ravn, 1998) indicate that absent a welfare state, the investment boom is amplified, since the interest rate does not increase as in the baseline case, and this makes both high-skilled hours and hours in efficiency units decline. Also, the current account balance, which was assumed to be in equilibrium at time 0, goes temporarily in a deficit (up to 20% of GDP) and foreign bond holdings, which were assumed positive at time 0, become negative over the adjustment path. In the long run the current account balance returns in equilibrium as the investment boom is reversed while foreign debt accumulates to about 25% of GDP.[13]

Finally, it is worth mentioning that the state of affairs may turn out to be less gloomy than described if the retraining effort is successful in increasing the productivity of labor and contrasting the negative effects due to changes in the capital-labor ratio. However, consistent with our analysis, Funke and Strulik (1997) suggest that even in the presence of sustained human capital accumulation, the adjustment process may be slow. Whether Germany has joined Italy and other Western nations in creating a dual economy (see Hughes-Hallett and Ma, 1993, and Boltho, Carlin, and Scaramozzino, 1997) or whether the adjustment process will eventually return Germany to its pre-unification standards is a question which requires more detailed studies and a few more years of data to receive a definitive answer.

[13] The unification produced a surge in the unemployment rate, with the low-skilled portion of the population being mostly affected. Clearly our model with competitive labor markets cannot replicate this fact. However, we can produce unemployment in the low-skilled portion of the population if we impose some kind of wage rigidity. Overall, adding unemployment does not change the major features of our results (see Canova and Ravn, 1998).

APPENDIX

In this appendix we describe our method to solve for aggregate and sectorial variables from the optimality conditions of different cohorts. First note that all low-skilled households are identical because they do not hold any capital and because the survival probabilities are independent of age. Second, the aggregate decision rule for high-skilled agents can be computed as follows.

The "consumption function" of a high-skilled household of cohort a at date t can be obtained by taking a first order Taylor approximation to (23). The consumption function is given by

$$c^s_{a,t} = R^s_t[1 - (1 - e)\beta](k^s_{a,t} + m^s_{a,t}),$$

where $R^s_t = (1 + (1 - \tau^s_t)r_t - \delta)$ and $m^s_{a,t} = (1/R^s_t)E_t\sum^{\infty}_{j=0}((1 - e)^j/R^s_{t,t+j})(1 - \tau_{t+j})w^s_{t+j}h^s_{a+j,t+j}$ is the expected human capital of an agent of cohort a at date t and $R^s_{t,t+j} = \prod^j_{i=1} R^s_{t+i}$, $R^s_{t,t} \equiv 1$.

Using (22) this can be rewritten as

$$c^s_{a,t} = R^s_t \frac{[1 - (1 - e)\beta]}{1 + A}(k^s_{a,t} + q^s_t),$$

where $q^s_t = (1/R^s_t)E_t\sum^{\infty}_{j=0}((1 - e)^j/R^s_{t,t+j})(1 - \tau_{t+j})w^s_{t+j}$.

Aggregate per-capita consumption, capital, and hours for high-skilled agents are then

$$c^s_t = \sum_{a=0}^{\infty} N^s_{a,t}c^s_{a,t}/N^s_t = R^s_t \frac{[1 - (1 - e)\beta]}{1 + A}(k^s_t + q^s_t) \tag{31}$$

$$k^s_t = \sum_{a=0}^{\infty} N^s_{a,t}k^s_{a,t}/N^s_t \tag{32}$$

$$h^s_t = \sum_{a=0}^{\infty} N^s_{a,t}h^s_{a,t}/N^s_t = 1 - \frac{Ac^s_t}{w^s_t(1 - \tau^s_t)}. \tag{33}$$

Combining the capital accumulation equation with the budget constraint of high-skilled agents of cohort a gives us $k^s_{a+1,t+1} = \frac{1}{1 - \pi}[(1 - \delta)k^s_{a,t} + (w^s_t h^s_{a,t} + r_t k^s_{a,t})(1 - \tau^s_t) - c^s_{a,t}]$. Aggregating this expression gives

$$K^s_{t+1} = [(1 - \delta)K^s_t + (w^s_t H^s_t + r_t K^s_t)(1 - \tau^s_t) - C^s_t]$$

or

$$\frac{N^s_{t+1}}{N^s_t}k^s_{t+1} = [(1 - \delta)k^s_t + (w^s_t h^s_t + r_t k^s_t)(1 - \tau^s_t) - c^s_t], \tag{34}$$

where K_t^s is the total beginning of period t skilled holdings of capital, H_t^s denotes total high-skilled hours worked, and C_t^s is total high-skilled consumption. Note that while the individual return to capital accumulation is $(1 + r_t(1 - \tau_t^s) - \delta)/(1 - \pi)$, the return to capital accumulation in the aggregate high-skilled population is equal to $(1 + r_t(1 - \tau_t^s) - \delta)$.

Note that Eqs. (31)–(34) do not involve the distribution of variables over cohorts of high-skilled agents so that a straightforward numerical solution procedure can be used.

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