Regional income convergence, skilled migration and productivity response: Explaining relative stagnation in the periphery*

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Abstract
Most country growth experiences imply urbanization with labor migration from poor to rich regions and relative stagnation in the periphery. We study mechanisms holding back regional income convergence emphasizing the importance of productivity. Recent research has addressed the effects of labor mobility for income convergence in the neoclassical growth model, but finds that migration has limited effect on the convergence process. We build skilled labor migration into a multi-regional neoclassical growth model and assume that skilled labor affects productivity. The formulation takes advantage of open economy growth models where human capital influences innovation and technology adoption. Skilled labor outmigration from periphery regions reduces the capacity to generate productivity growth. Calibration of the regional growth model shows that skilled outmigration has quantitative importance for the growth performance of the periphery with realistic parameters. The analysis of the consequences of capital shock reproducing backwardness shows how migration equilibrium can be reestablished only after prolonged relative stagnation.

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1. Introduction

The starting point of this analysis is the observation of seemingly permanent imbalances between regions in most countries and associated skilled labor migration out of the periphery. Poor regions stay poor for extended periods and economic growth is concentrated to urban areas. The standard neoclassical model with income convergence cannot explain long term relative stagnation of the periphery. Interestingly, recent extension of the neoclassical model taking into account labor outmigration does not modify the underlying income convergence much (Rappaport, 2005).

To understand how regional income convergence is held back we introduce mechanisms from open economy growth theory emphasizing endogenous productivity. Benhabib and Spiegel (1994, 2005) show how human capital influences innovation and technology adoption in a model in the tradition of Nelson and Phelps (1966). While this model of catching up growth generally strengthens the case for low income regions and countries to convergence, the human capital effect can turn the story around. An extensive theoretical and empirical literature on productivity growth finds that skill intensity affects innovation and adoption. We suggest that skilled labor migration with productivity effect is an important aspect of the income convergence process in practice, in particular in a regional context. The paper analyzes regional growth in an intertemporal model of two regions showing how outmigration of skilled labor with consequences for productivity growth explains relative stagnation in the periphery region.

Recent analyses of regional growth have addressed the role of skilled labor in the productivity growth process. Aghion et al. (2005) analyze the US states and show that skilled outmigration from poor regions will reduce the growth effect of the technology gap. When the periphery loses important human capital, low income regions may not be able to catch up. Rattsø (2008) confirms the importance of labor outmigration to understand the development of the periphery using regional data from Norway.

Our starting point is the Rappaport (2000, 2005) framework extending the neoclassical growth model with labor mobility. We concentrate on skilled labor migration and add endogenous productivity response to skilled outmigration in accordance with Benhabib and Spiegel (1994, 2005). The skill intensity affects productivity through both innovation and technology adoption. The economy consists of a small region, which is the focus of our study, and the rest of the economy. The representative household is forward looking and maximizes its intertemporal utility, while the investment decision follows from intertemporal profit maximization. At the production side we separate between skilled and unskilled labor to capture the fact that skilled workers are more mobile and are more important for the productivity growth. Skilled workers in the small region make their migration decision based on utility comparisons across regions. To be discussed below the conditions for migration equilibrium are important for the long run growth.

The model analysis simulates the development of a low income region relative to the rest of the economy. We impose a negative capital shock in the small region that leaves the initial output per capita at 60% of the rest of economy level. In the standard neoclassical model version with exogenous productivity growth and no labor mobility, the negative capital shock is followed by rapid convergence back to steady state. When we allow for labor migration, convergence is slower, but the effect is limited. It takes the regional economy 26 years rather than 23 years to reach 95% of the rest of economy level of output per capita. Our introduction of a linkage between skilled outmigration and productivity growth strongly holds back convergence and leads to persistent relative stagnation in the backward region. The model assumes a long run steady state with equal growth rates and migration equilibrium, but even after 50 years output per capita is only about 93% of the rest of economy level. Outmigration of skilled workers reduces the periphery region's capacity to generate productivity growth. The drop in relative productivity affects output per capita convergence both directly and indirectly by lowering the marginal return to capital. The profitability of capital investments is also held back by the prolonged decline in the regional skilled population during transition.

The linkages back to neoclassical income convergence and open economy catching up are explored in section 2. The multi-regional intertemporal model with skilled migration and skilled-driven productivity is outlined in section 3. Section 4 offers the analysis of a capital shock disturbing the balance between the region under study and the rest of the economy. The discussion deals with both immediate and long run adjustments. Section 5 investigates the robustness of the results. Concluding remarks are presented in section 6.

2. Income convergence and catching up

The dominating theoretical framework of regional income gaps is the Rosen-Roback model (Rosen, 1979, Roback, 1982). The model interprets regional differences in wages and rents as compensating firms and residents for inter-regional differences in amenities. The spatial equilibrium of the model is characterized by identical levels of utility and profits across locations. Quality of life and productivity motivate location of households and firms respectively, and compensating wage and land price differentials establish equilibrium. In this static framework higher wage level and lower price of land in the periphery can be understood as the result of a positive quality of life shock in urban areas. The equilibrium response in the periphery is to have higher wage level and lower price of land to compensate the households for the relative shift in quality of life. The reduction in the price of land is necessary to defend the profit level in the periphery.

This stylized static model can explain income and population levels in periphery and urban regions. The model predicts high population density in regions with high levels of productivity and quality of life. The shift in incomes will reflect compensating changes of factor prices and may imply periods of changes in relative wages to the advantage of the periphery.

Rappaport (1999, 2000, 2004, 2005) investigates the role of labor mobility in a neoclassical growth model to reach a better understanding of the dynamic processes involved. Adjustment costs of capital investment and population flows generate transition paths describing the responses to shocks in capital stock, productivity and utility (quality of life). Rappaport (1999, p. 8) analyzes a positive quality of life shock (in a model where firms are independent of the price of land). He shows how the inflow of labor causes the marginal product of labor to decrease and wages to fall. The key intuition of the neoclassical growth model is that labor mobility out of poor regions will speed up wage equalization and thereby income convergence. But the labor outmigration also is expected to reduce the marginal productivity of capital and can lead to disinvestment. Rappaport (2005) concludes based on numerical simulations that labor mobility overall is expected to increase the speed of wage convergence. Evans (1997) shows that speed of convergence is higher for U.S. states than for countries. The labor supply reductions in the periphery and the labor supply increases in the urban centers, implicit in the Rappaport model version, contribute to the wage response underlying the convergence.

The Rosen-Roback and Rappaport models offer insight about the effects of labor mobility for regional income levels and growth. Both approaches concentrate on the interplay between capital and labor and are consistent with income convergence. The open economy growth literature has expanded the understanding of growth by including international spillovers of knowledge and technology. Catching up growth is based on the capacity to take benefit of the world technology frontier (Caselli and Coleman, 2006, Lucas, 2007, empirical support by Coe et al., 1997) through spillovers of technology and knowledge. Regions within a country are expected to have low barriers to such spillovers and the catching up mechanism is expected to be powerful. All these models predict income convergence and catching up strengthens convergence.

The analysis of relative stagnation in the periphery typically looks at very different models. Economic geography has contributed to the understanding of growth centers and with agglomeration as the key concept. Agglomeration describes the productivity externalities achieved with spatial concentration. Fujita and Thisse (2003) offer a growth model of particular relevance for us. They also assume migration of skilled labor and study knowledge externalities among skilled workers and productivity spillovers. Their analysis shows how migration of firms and households to the core generates agglomeration effects and higher growth. They conclude that even those left behind in the periphery may be better off. Another large literature deals with poverty traps to explain persistent stagnation of poor countries. Azariadis and Stachurski (2005) give a nice overview of multiple-equilibria in growth models possibly explaining low growth over long time. Such traps preventing the adoption of new technologies seem less relevant in a regional context with high mobility of all factors of production.

In this analysis we focus on the periphery region and attempt at explaining stagnation in a neoclassical framework extended to take into account endogenous productivity. The extension introduces skilled labor migration and the effects of skill or human capital for the ability to adopt knowledge and technology as studied by Benhabib and Spiegel (1994, 2005). The role of skilled labor for growth has been investigated recently in the regional context of the US states by Aghion et al. (2005). They show that skilled migration out of poor states reduces the growth effect of the technology gap. They offer an interesting identification strategy to investigate the role of education and conclude that graduate education will be most growth enhancing for regions close to the technology frontier, while secondary education will be most growth enhancing for regions far from the frontier. Our contribution is to link the skill-productivity mechanism to the neoclassical growth model to analyze balanced and unbalanced growth between regions.

3. Intertemporal model of regional growth

We extend the intertemporal neoclassical growth model with labor mobility designed by Rappaport (2000). First, we separate between skilled and unskilled labor to capture the fact that skilled workers are more mobile and are more important for the productivity growth. Second, we build in endogenous productivity dynamics with a relationship between stock of skilled workers and productivity. As discussed in section 2, this relationship is introduced in the catching up literature and interpreted as human capital affecting the barriers to technology adoption. But more broadly the stock of skilled labor is expected to influence both innovation and adoption.

Sections 3.1-3.3 describe the production technology and the intertemporal dynamics, which are common to the small region and the rest of the economy. Section 3.4 presents the migration decision facing skilled workers in the region of our study. In section 3.5 we endogenize regional productivity growth, which is the main extension compared to Rappaport. Finally, section 3.6 discusses the long-run properties of the model. The large region (the rest of the economy) is always in its steady state.

3.1 Production technology

Value added (X_t) is defined as a Cobb-Douglas function of capital (K_t) and aggregate effective labor (Lab_t), where the latter is a CES-function of unskilled labor (Lu), skilled labor (Ls_t):

$$X_t = A_t^{\alpha} Lab_t^{\alpha} K_t^{1-\alpha} \tag{1}$$

$$Lab_t = \left(\beta Lu^{-\varepsilon} + (1-\beta) Ls_t^{-\varepsilon}\right)^{-1/\varepsilon} \tag{2}$$

The elasticity of substitution between unskilled and skilled labor is defined as $\sigma = \frac{1}{1+\varepsilon}$ ($\varepsilon > -1$ and $\varepsilon \neq 0$). Labor augmenting technical progress (A_t) in the small region is endogenously determined, as explained in section 3.5. The first order conditions equilibrate factor prices with the marginal productivity of each factor:

$$\alpha X_t \beta Lu^{-\varepsilon-1} = wu_t Lab_t^{-\varepsilon} \tag{3}$$

$$\alpha X_t (1-\beta) Ls_t^{-\varepsilon-1} = ws_t Lab_t^{-\varepsilon} \tag{4}$$

$$(1-\alpha) X_t = Rk_t K_t \tag{5}$$

where wu_t is the unskilled wage rate, ws_t is the skilled wage rate, and Rk_t is the capital rental rate. In the small region the supply of unskilled labor is constant, while the skilled labor force develops endogenously according to the migration equation described in section 3.4. In the rest of the economy both unskilled and skilled labor forces are constant over time[1].

3.2 The investment decision

The representative firm makes its investment decision according to intertemporal profit maximization, subject to the accumulation of the capital stock over time:

$$\underset{I,K}{Max} \sum_{t=1}^{\infty} (1+r)^{-t} \left[Rk_t \cdot K_t - (1+ADJ_t) I_t \right] \tag{6}$$

$$s.t.\ K_{t+1} = K_t \cdot (1-\delta) + I_t \tag{7}$$

where r is the exogenous world market interest rate, I_t is investments, ADJ_t is unit adjustment costs in investment, and δ is the rate of depreciation. Following the common practice in the literature, unit adjustment costs are specified as a positive function of the investment-capital ratio:

$$ADJ_t = a \cdot \frac{I_t}{K_t} \tag{8}$$

where a is a constant parameter.

Differentiating the intertemporal profit function with respect to I_t gives:

$$q_t = 1 + 2 \cdot a \cdot \frac{I_t}{K_t} \tag{9}$$

[1] We ignore population growth.

This relationship says that the investor equilibrates the marginal cost of investment, which is given on the right hand side, and the shadow price of capital, q. Differentiating the same function with respect to K_t gives us the well-known no-arbitrage condition:

$$r \cdot q_{t-1} = Rk_t + a \cdot \left(\frac{I_t}{K_t} \right)^2 - \delta \cdot q_t + \dot{q}_t \tag{10}$$

Equation (10) states that the marginal return to capital must equal the interest payments on a perfectly substitutable asset with a value of q_{t-1}, where q is the shadow price of capital. The first term on the right-hand side is the capital rental rate, while the second term is the partial derivative of the adjustment cost function with respect to capital. The marginal return to capital must be adjusted by the depreciation rate and by the capital gain or loss, $\dot{q}_t$.

3.3 Utility maximization

The representative household derives utility from consumption of output goods (c_t) and of housing services (n_t). The composite household supplies skilled and unskilled labor with common demand for consumption and housing. The household is forward looking and maximizes an intertemporal utility function taking into account the lifetime budget constraint:

$$Max \;\; U_t = \sum_{s=t}^{\infty} (1+\rho)^{-(s-t+1)} u(c_s, n_s) \tag{11}$$

$$s.t. \; \sum_{s=t}^{\infty} (1+r)^{-(s-t+1)} (c_s + p_s n_s) = TW_t \tag{12}$$

where ρ is the positive rate of time preference, and p_t is the rental price of housing services. Assuming intertemporal elasticity of substitution equal to unity, the utility function is defined as $u(c_t, n_t) = (1-\gamma)\ln c_t + \gamma \ln n_t$, where γ is the share of total spending going to housing services. TW_t is total wealth at time period t, which equals the sum of asset wealth and the net present value of wages (labor wealth). Aggregate labor wealth (LW_t) equals the sum of unskilled and skilled labor wealth (LWu_t and LWs_t, respectively), weighted by population shares:

$$TW_t = Asset_t + LW_t \tag{13}$$

$$LW_t = \frac{Lu}{L_t} LWu_t + \frac{Ls_t}{L_t} LWs_t \tag{14}$$

$$LWu_t = \sum_{s=t}^{\infty} (1+r)^{-(s-t+1)} wu_s \tag{15}$$

$$LWs_t = \sum_{s=t}^{\infty} (1+r)^{-(s-t+1)} ws_s \tag{16}$$

Asset accumulation is given by:

$$Asset_{t+1} = (1+r)Asset_t + w_t - c_t - p_t n_t \tag{17}$$

where w_t is the sum of skilled and unskilled wages weighted by population shares.

From the utility maximization it follows that the household at any time uses a fraction $\rho(1+g)$ of its total wealth on consumption of output goods and housing services:

$$c_t = (1-\gamma)\rho(1+g)TW_t \tag{18}$$

$$p_t n_t = \gamma\rho(1+g)TW_t \tag{19}$$

where *g* is the exogenous long-run growth rate.

Combining equations (17)-(19), the annual change in asset wealth can be written as:

$$Asset_{t+1} - Asset_t = (r - \rho(1+g))Asset_t + w_t - \rho(1+g)LW_t \tag{20}$$

While the per capita demand for housing services is given by equation (19), the aggregate supply of housing services (*N*) is constant. The rental price of housing is endogenously determined to clear the housing market:

$$\frac{N}{L_t} = n_t \Rightarrow p_t = \gamma\rho(1+g)\frac{L_t}{N}TW_t \tag{21}$$

where $L_t = Lu + Ls_t$ is total population in the region (which in the small region may vary during transition depending on the degree of labor mobility). To avoid unstable processes with gradual disappearance of a region, we assume away history dependence by setting last period asset wealth equal between the small region and the rest of the economy. We see this as a necessary technicality when we do not allow adjustment of housing supply.

The utility maximization gives the Euler equations for optimal allocation of output good consumption and housing services consumption over time:

$$\frac{c_{t+1}}{c_t} = \frac{1+r}{1+\rho} \tag{22}$$

$$\frac{p_{t+1}n_{t+1}}{p_t n_t} = \frac{1+r}{1+\rho} \tag{23}$$

Consumption of output goods and total spending on housing services grow exogenously at the long-run rate.

3.4 Skilled migration equilibrium

We assume that unskilled labor is immobile, while skilled labor is mobile, to highlight the productivity dynamics influenced by skill. The skilled migration equilibrium sets additional constraints to the household utility functions. Following Rappaport (2000), the utility cost associated with migration is assumed to be proportional to the rate of net migration:

$$U_{i \to row}^{\text{cost}} = b_L \left(\hat{L}s_{row,t} - \hat{L}s_t \right) = -b_L \hat{L}s_t \qquad \text{(Outmigration, } \hat{L}s_t < 0\text{)} \tag{24}$$

$$U_{row \to i}^{\text{cost}} = b_L \left(-\hat{L}s_{row,t} + \hat{L}s_t \right) = b_L \hat{L}s_t \qquad \text{(Inmigration, } \hat{L}s_t > 0\text{)} \tag{25}$$

where arrows indicate the direction of net migration (*i* = small region, *row* = rest of economy). Since the rest of the economy is large compared to the region of our study, its population is assumed to be unaffected by the migration ($\hat{L}s_{row,t} = 0$).

Based on the consumption functions in equations (18) and (19) the household's lifetime utility function can be decomposed as follows:

$$U_t = f(\rho, \gamma, r) + \frac{\ln TW_t}{\rho} - \gamma \sum_{s=t}^{\infty} (1+\rho)^{-(s-t+1)} \ln p_s \tag{26}$$

The first term depends on exogenous parameters, the second term on the household's total wealth, and the third term depends on the time path of housing rental prices. A similar utility decomposition exists for the rest of the economy:

$$U_{row,t} = f(\rho, \gamma, r) + \frac{\ln TW_{row,t}}{\rho} - \gamma \sum_{s=t}^{\infty} (1+\rho)^{-(s-t+1)} \ln p_{row,s} \tag{27}$$

The utility gain from living in the small region can then be expressed as follows:

$$dU_t = U_t - U_{row,t}$$

$$= \frac{1}{\rho} \ln\left(\frac{TW_t}{TW_{row,t}} \right) + \gamma \sum_{s=t}^{\infty} (1+\rho)^{-(s-t+1)} \ln\left(\frac{p_{row,s}}{p_s} \right) \tag{28}$$

Since only skilled workers migrate, differences in unskilled labor wealth do not matter for the migration decision. It is further assumed that migration do not change the asset wealth of households. To take this into account, equality of unskilled labor wealth and asset wealth across regions is imposed on equation (28). The utility gain facing skilled workers is then specified as follows:

$$dU_t = \frac{1+\rho}{\rho} \ln\left(\frac{\frac{Lu}{L} LWu_t + \frac{Ls}{L} LWs_t + Asset_t}{\frac{Lu}{L} LWu_t + \frac{Ls}{L} LWs_{row,t} + Asset_t} \right) + \gamma \sum_{s=t}^{\infty} (1+\rho)^{-(s-t+1)} \ln\left(\frac{p_{row,s}}{p_s} \right) \tag{29}$$

The specification captures that skilled migration is driven by differences in skilled labor wealth and housing prices. Since the population shares affect total wealth, but not the migration decision of skilled workers, they are assumed constant at the steady state level.

In equilibrium the cost of migration equals the gains from migration. This implies that the development in the small region's skilled population is given as:

$$\hat{Ls}_t = \frac{dU_t}{b_L} \tag{30}$$

The parameter b_L is a measure of the degree of labor mobility, and is calibrated based on the relative total wealth needed to induce one percent rate of net migration (given equal housing prices across regions).

3.5 Endogenous productivity response to migration

We start out from the productivity formulation suggested by Benhabib and Spiegel (1994), which is an extension of the technology adoption function of Nelson and Phelps (1966). Productivity growth is related to the gap to the world technology frontier and the level of human capital. We assume that both the innovation and adoption elements of productivity growth are influenced by the endogenous migration of skilled labor. The empirical literature suggests that skill does not enter the productivity relation as a scale effect. Consistent with the long run properties of the model we use the share of skilled workers in the regional labor force (Ls_t / L_t) as argument. The specification is consistent with the catching-up hypothesis and implies technological convergence. Backward economies have a relative advantage due to large learning potential and catch-up towards the world frontier. In the long-run, regional productivity growth equals the exogenous long-run rate and the technology gap is constant.

Productivity growth in the small region is specified as follows:

$$\hat{A}_t = \left(\frac{Ls_t}{L_t}\right)^{\theta_1} + \lambda\left(\frac{Ls_t}{L_t}\right)^{\theta_2}\left(\frac{A_t^*}{A_t} - 1\right) \tag{31}$$

The first term on the right-hand side of equation (31) represents the contribution from innovation activities, while the second term is the technology adoption function. A_t and A_t^* are the regional and world frontier level of productivity, respectively. The productivity level at the frontier grows exogenously at the long-run rate. λ, θ_1 and θ_2 are constant parameters.

3.6 Long-run constraints

A multi-regional intertemporal framework offers dynamic restrictions to the economic growth of regions. The standard steady state condition in this type of setup assumes that regions grow in balance with common growth rates. The explanation is simple; any difference in growth rates will lead to the disappearance of the low growth region. The 'problem' is similar in multisectoral growth models and has been analyzed in particular in the relationship between agriculture and industry (Matsuyama, 1992). Since balanced growth between agriculture and industry is not observed, some ad hoc assumptions are needed to explain the steady shrinking of the agricultural part of the economy.

Capital and labor will tend to move to a region with higher long run productivity level than the rest of the economy. Long run balance between regions requires the same productivity level for all. The alternative is full collapse of one region. Combined with mobility of both labor and capital this steady state condition is forceful in securing regional allocation of labor and capital with equal returns across space. Shocks to the regional balance consequently will give transitory movements of resources with regional unbalance.

In the long run equilibrium the capital stock and labor wealth (both for unskilled and skilled workers) grow at the exogenous rate *g* and the marginal return to capital is constant:

$$I_t = (\delta + g)K_t \tag{32}$$

$$(r+\delta)q_t = Rk_t + a\left(\frac{I_t}{K_t}\right)^2 \tag{33}$$

$$LWu_t = \frac{wu_t}{r-g} \tag{34}$$

$$LWs_t = \frac{ws_t}{r-g} \tag{35}$$

By combining equations (14) and (20) with the steady state conditions of unskilled and skilled labor wealth, long-run asset wealth is shown to grow at the exogenous rate.[2] The utility levels are equalized across regions and populations are constant. Output, wages, investment, output good consumption, housing rental price, total wealth, and productivity (including world frontier productivity) all grow at the exogenous long-run rate. Other variables are constant.

4. Capital shock analysis

The analysis of the model addresses the development of a low income region relative to the rest of the economy. We impose a negative capital shock in the small region to simulate the growth out of backwardness. The calibration of the capital shock leaves the initial wage rate and output per capita at 60% of the rest of economy level. Numerical simulations illustrate the transition paths back to steady state.[3] We focus on a 50 year period that captures both the immediate and the longer term response to the capital shock.

In the standard neoclassical model version with exogenous productivity growth and no labor mobility, the negative capital shock is followed by rapid convergence back to steady state. As seen from Figure 1, regional output per capita reaches 95% of the rest of economy level after 23 years. The convergence is driven by rapid investment growth taking advantage of high marginal return to capital. Adjustment costs in investment hold back the expansion and generate transition dynamics.

Figure 1 about here.

In a series of papers Rappaport extends the neoclassical growth model to allow for labor migration. His analysis focuses on the impact of labor mobility on wage convergence, while we concentrate on the output per capita effects. In Figure 1 we compare the negative capital

[2] From the Euler equations it follows that $1+g = \frac{1+r}{1+\rho}$, which implies that $\frac{1+r}{r-g} = \frac{1+\rho}{\rho}$. These relationships are applied in the calculation of long-run asset growth.

[3] The calibration of parameters is described in the appendix.

shock response in the standard neoclassical model to the case with labor mobility. We assume that 0.54% difference in total wealth induces 1% annual rate of net migration ($\omega = 1.0054$), which is consistent with empirical estimates of labor mobility offered by Gallin (2004).[4] The initial wage difference between the small region and the rest of economy generates temporary labor outmigration with consequences for the transition dynamics. The outmigration creates a disincentive for capital investment, but the effect on output per capita convergence is limited. When we allow for labor mobility, it takes the region 26 years (rather than 23 years) to reach 95% of the output per capita level of the rest of economy.

In accordance with Rappaport (2005) we find that labor mobility does not affect income convergence much. It follows that labor outmigration alone cannot explain the prolonged relative stagnation observed in the periphery. We suggest an additional mechanism important for the development of the periphery, skilled outmigration affecting productivity dynamics. The initial skilled labor outmigration (illustrated in Figure 2) reduces the region's capacity to generate productivity growth. The share of skilled workers in total regional population decreases rapidly from 60% to 54.5% during the first 16 years. Relative productivity decreases gradually over time, and after 50 years the regional productivity level equals 95% of the rest of economy level (see Figure 3). Relative productivity reaches its minimum after 55 years, followed by a (very) slow return to the national productivity level.

Figure 2 and 3 about here.

The labor market adjustments are an important part of the relative stagnation in the periphery. Lower relative productivity holds back the skilled wage convergence. Large outmigration during the first years increases the marginal productivity of skilled labor, and contributes to rapid wage convergence[5]. With exogenous productivity growth, the relative skilled wage increases from 60% to 95% during the first 18 years, and after 50 years the wage gap is eliminated. When outmigration affects relative productivity, the initial surge in the relative wage is smaller, and is followed by stagnation and very slowly decreasing wage gap between the small region and the rest of the economy. After 100 years, the regional skilled wage rate is still only 97% of the rest of economy rate. This implies that the incentive of skilled workers to

[4] Based on data for US states, Gallin (2004) finds that a 1% wage difference that lasts for 1 year, generates a net migration rate of 0.09%. As illustrated by Rappaport (2005, footnote 3, p. 572), this result implies that 0.54% difference in total wealth induces 1% annual rate of net migration.

[5] The fall in the marginal productivity of capital following outmigration works in the opposite direction.

move back into the region is limited, even though regional housing prices are lower than in the rest of the economy. As seen from Figure 2, the regional skilled population equals about 85% of its steady state level after 50 years, compared to 96% in the exogenous productivity scenario. The slow return of skilled workers holds back the productivity catch-up, which again prolongs the skilled wage gap between the small region and the rest of the economy and reinforces the slow return of skilled workers.

The combined effect of lower relative productivity and prolonged outmigration is to slow the output per capita convergence and generate a long period of stagnation. As seen from Figure 4, regional output per capita equals 93% of the rest of economy level after 50 years, compared to 99% when the productivity response to skilled migration is ignored. Relative output per capita increases slowly over time and is still below 95% after 100 years. The drop in relative productivity affects output per capita convergence both directly and indirectly by lowering the marginal return to capital. The profitability of capital investments is also held back by the prolonged decline in the regional skilled population during transition.

Figure 4 about here.

The skilled labor outmigration and consequent negative productivity growth effect is a powerful mechanism to explain the persistent stagnation of periphery regions in countries, and also holds relevance for poor countries suffering from brain drain. It has long been a concern in the growth literature that the neoclassical model cannot reproduce regions in long term stagnation. The investment convergence mechanism is an essential aspect of the model. The empirical appeal to conditional convergence based on additional constraining factors does not modify the underlying adjustment process. The extension of Rappaport to include labor migration certainly increases the relevance of the model for the analysis of regional growth with open labor markets. Interestingly, labor outmigration from poor regions does not contribute much to prolonged stagnation. The outmigration raises the marginal product of labor and consequently speeds up the wage convergence. Income convergence is held back by the associated disincentive to invest. But as we have shown above, with realistic stylized parameters of the model the slowing down of income convergence is limited.

The dynamic growth process changes character when skilled labor outmigration is assumed to have consequences for productivity growth. A large literature of open economy growth has shown theoretically and empirically how human capital affects productivity growth. Benhabib and Spiegel (1994) show how human capital affects total factor productivity in cross country data. In an analysis of 19 OECD countries during 1960-2000 Vandenbussche et al. (2006) find that human capital (measured by the share of the adult population with some tertiary education) stimulates TFP growth, and that the positive effect of human capital decreases with the distance to the technological frontier. Our formulation captures the effects for both innovation and adoption of migration of skilled labor and the sizes of the effects are calibrated consistent with the results of Vandenbusche et al.. We have shown above that this mechanism is able to dominate the income convergence effect and lead to persistent stagnation in backward regions. In a similar way, brain drain in terms of outmigration of skilled labor can explain long term stagnation in poor countries.

The literature on regional growth has concentrated more on the urban side of the growth process, notably geographical agglomeration. In the comparable two-region model of Fujita and Thisse (2003), their main alternative scenario implies that skilled labor, innovation activity and modern sector production concentrate to the urban region while the periphery region specializes in the traditional sector. Skilled labor migration equilibrium is taken care of by having all skilled labor move to the center. The periphery can gain when the agglomeration effects are strong enough to raise the demand for traditional sector goods sufficiently. The income convergence mechanisms working at the labor and capital markets of the periphery are strongly weakened in their setup. They do not capture the productivity effects in the periphery associated with skilled labor outmigration that we focus on.

The model setup here assumes long term migration equilibrium. In this case the economies must reestablish equality of productivity and utility levels. Outmigration takes place as long as households can gain utility from moving. If the stagnating region shall avoid full collapse, at some stage there must be a turnaround with improved productivity and utility. The analysis shows that the negative productivity effect of skilled outmigration is likely to be hard to counteract. When only a capital shock is imposed, the fundamental economic conditions of the region have not been changed. In this case we will eventually have a return to the initial balance between the regions.

5. Robustness of results

So far, we have shown that for a given degree of labor mobility output per capita convergence is slower when the endogenous productivity response to labor migration is taken into account. To investigate the robustness of the results above we compare scenarios with high and low labor mobility. The degree of mobility obviously affects the speed of convergence. In the high mobility case 0.125% difference in total wealth is sufficient to induce 1% annual rate of net migration ($\omega = 1.00125$), while the low mobility case requires 8% wealth difference to generate the same rate of net migration ($\omega = 1.08$).

Higher degree of labor mobility implies immediately larger outmigration as a response to the initial wage gap. Since the capacity to generate productivity growth depends on the share of skilled workers in the population, the productivity decline increases with the degree of labor mobility (see Figure 5). As illustrated in Figure 6, higher mobility implies slower convergence in capital per worker. Higher labor mobility affects the marginal return to capital negatively through larger outmigration and through larger decline in relative productivity. By comparing with the case of exogenous productivity growth we find that the slower convergence in capital per worker with high mobility mainly follows from lower relative productivity.

Figure 5 and 6 about here.

The mechanisms described above imply slower convergence in output per capita when the degree of labor mobility is high, working via both relative productivity and capital per worker. In the low and high mobility case, it takes the regional economy 16 and 50 years, respectively, to reach 90% of the rest of economy level (Figure 7). When the productivity response to outmigration is ignored, the degree of labor mobility has limited effects on the speed of convergence in output per capita (Figure 8). In this case, convergence is not held back by larger relative productivity decline as labor mobility increases. In addition, the effect of labor mobility on capital profitability is much weaker, since this mainly works via the productivity channel.

Figure 7 and 8 about here.

6. Concluding remarks

The starting point of this analysis is the observation of seemingly permanent imbalances between regions in countries and the importance of labor migration for the economic adjustments. Poor regions stay poor for extended periods and labor migration out of poor regions characterizes the growth process of most countries. The standard neoclassical model with income convergence cannot explain long term stagnation. Interestingly, recent extension of the neoclassical model taking into account labor outmigration does not modify the underlying income convergence much.

We offer a new model to explain the observed stagnation where we combine the neoclassical model with labor migration and recent contributions in open economy growth linking human capital and productivity growth in both innovation and adoption. The migration of skilled labor influences the stock of human capital and thereby productivity growth. We have shown above that this mechanism is able to dominate the income convergence effect and lead to persistent stagnation in backward regions. In a similar way, brain drain in terms of outmigration of skilled labor can explain long term stagnation in poor countries.

The model analysis has addressed the effects of capital shock assumed to set the region studied into backwardness. Capital shock is inherently temporary and the dynamic process will eventually lead the economy back to the initial equilibrium. Future research will address the consequences of permanent shocks that change the fundamental factors determining the economic development of regions.

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Appendix: Calibration

The parameters of the productivity specification given in equation (31) are important for the numerical results, and are set according to available econometric estimates. The elasticity of productivity growth with respect to the skill ratio is given by θ_1 multiplied by the innovation share plus θ_2 multiplied by the adoption share. We set $\theta_1 = \theta_2 = 1.5$, which gives an elasticity of 1.5. If the share of skilled workers in the labor force increases with 1%, productivity growth increases with 1.5%, and the effect works via both innovation and technology adoption. This implies that an increase in the skill ratio of 10% points gives 0.6-1% point higher productivity growth when starting from the assumed steady state rate (2%)[6]. This corresponds to an increase in the TFP growth rate of 0.4-0.7% points[7]. We follow the analysis of 19 OECD countries during 1960-2000 by Vandenbussche et al. (2006) and evaluated at the average technology gap among the OECD countries in the analysis ($A/A^* = 0.74$) their results imply that 10% points higher skill ratio generates about 1% point higher TFP growth rate[8]. Compared with these results, the elasticity applied in our model can be seen as conservative.

The degree of labor mobility is measured by the relative wealth needed to induce 1% rate of net migration (given equal housing rental prices across regions), described by the parameter ω. In the model this is introduced via the parameter b_L in the migration equilibrium, which is calibrated consistent with the degree of labor mobility:

$$b_L = \frac{\frac{1+\rho}{\rho}\ln\omega}{0.01}$$

In the base-run simulations, we set $\omega = 1.0054$, which means that 0.54% difference in total wealth induces 1% annual rate of net migration. As documented in the text, this is consistent with estimates by Gallin (2004). The share of consumption expenditure devoted to housing services (γ) is set to 20%, which is broadly consistent with US data (Rappaport, 2000). The share of skilled workers in the labor force develops endogenously in the model based on the degree of migration. But its long-run steady state value is set in the calibration and is assumed

[6] The calculation is based on skill ratios in the range 0.3-0.6, which reflects the magnitudes in the model simulations.

[7] The relationship between the rate of labor augmenting technical progress and TFP growth is defined as $gTFP_t = \alpha \hat{A}_t$, where α is the aggregate labor share in the production function. The steady state TFP growth rate therefore equals 1.4%.

[8] The calculation is based on estimated coefficients in regression 5 of Table 4 in Vandenbussche et al. (2006). The average technology gap is given in their Table 1.

to equal 60%. This is consistent with average OECD data on the share of adult population with upper secondary or tertiary level of education (OECD, 2008)[9]. Appendix Table 1 gives an overview of the calibrated parameters and the long-run value of selected endogenous variables.

Appendix Table 1.

Calibrated parameters and steady state (SS) values of selected endogenous variables.

Parameter	**Description**	**Value**
r	World market interest rate	0.04
ρ	Time preference rate	0.02
g	Long-run growth rate	0.02
γ	Share of housing services in total spending	0.2
α	Aggregate labor share in production	0.7
$1-\alpha$	Capital share in production	0.3
β	Share parameter in labor CES function	0.34
σ	Elasticity of substitution between *Lu* and *Ls*	3.0
δ	Rate of depreciation	0.05
θ_1	Parameter in the productivity specification	1.5
θ_2	Parameter in the productivity specification	1.5
λ	Parameter in the productivity specification	4.96
a	Parameter in adjustment cost function	4.0
ω	Relative wealth needed to induce 1% net migration	1.0054
b_L	Parameter in the migration equilibrium	27.5
Variable	**Description**	**SS Value**
Wu/Ws	Unskilled wage rate relative to skilled wage rate	0.7
Rk	Capital rental rate	0.12
Adj	Unit investment adjustment costs	0.28
q	Shadow price of capital	1.56
K/X	Capital-output ratio	2.5
I/K	Investment rate	0.07
Ls/L	Share of skilled workers in total labor force	0.6

[9] Given in Table A1.1a: Educational attainment, adult population (2006).

Figure 1. Impact of negative capital shock on output per capita convergence: Standard neoclassical model versus neoclassical model with labor mobility (Exogenous productivity growth in both cases).

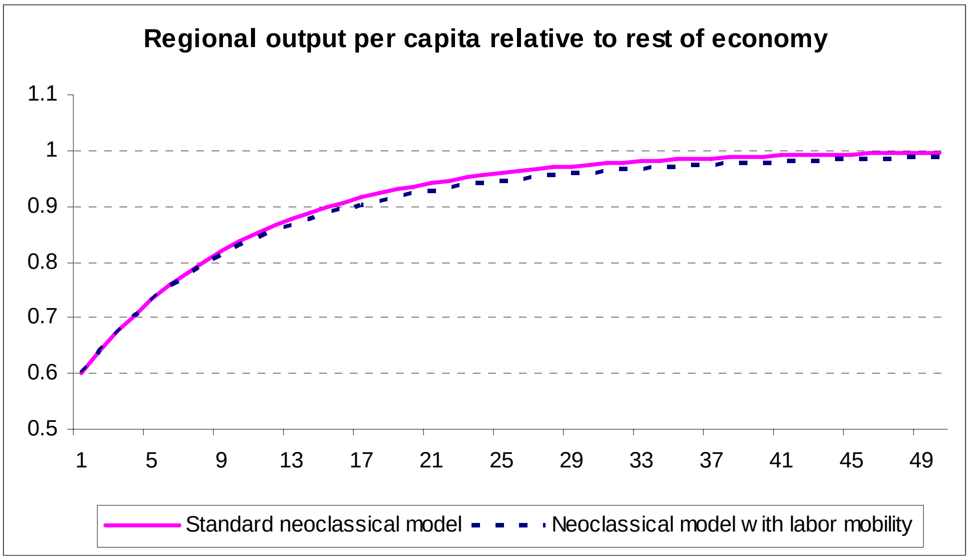

Figure 2. Impact of negative capital shock on skilled outmigration: Neoclassical model with labor mobility vs. neoclassical model with labor mobility and endogenous productivity response to migration.

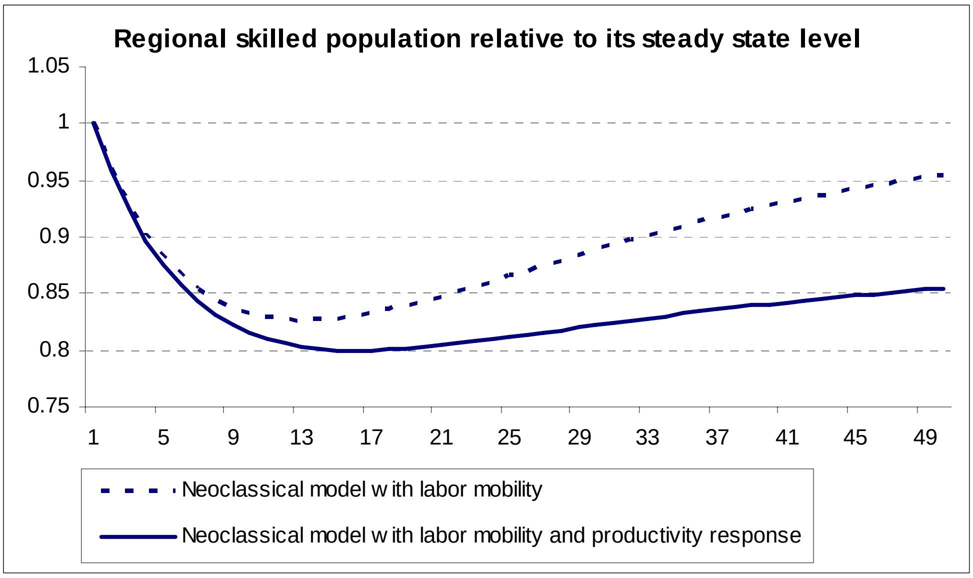

Figure 3. Impact of negative capital shock on relative productivity: Neoclassical model with labor mobility vs. neoclassical model with labor mobility and endogenous productivity response to migration.

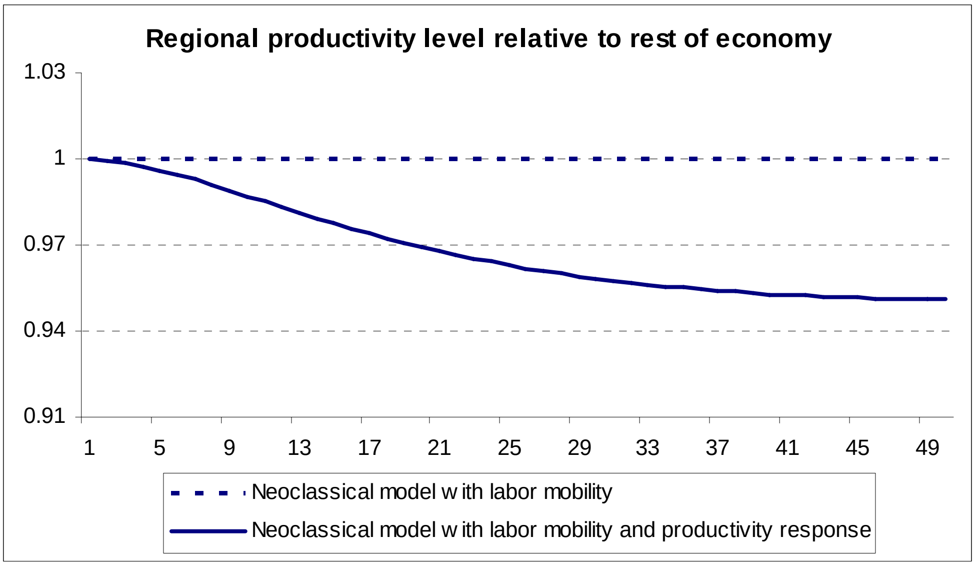

Figure 4. Impact of negative capital shock on output per capita convergence: Comparing standard neoclassical model, neoclassical model with labor mobility, and neoclassical model with labor mobility and endogenous productivity response to migration.

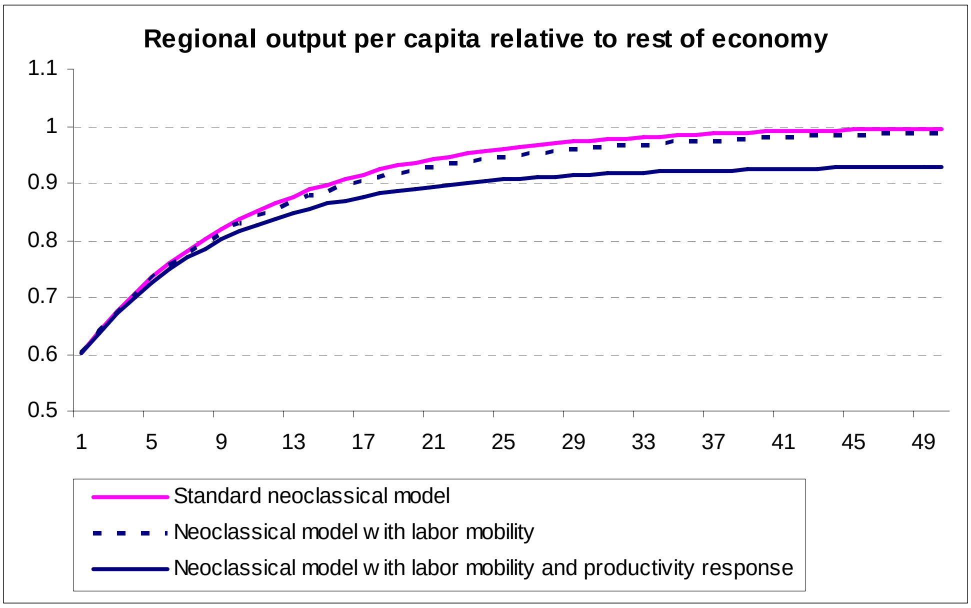

Figure 5. Impact of negative capital shock on relative productivity: Low vs. high degree of labor mobility.

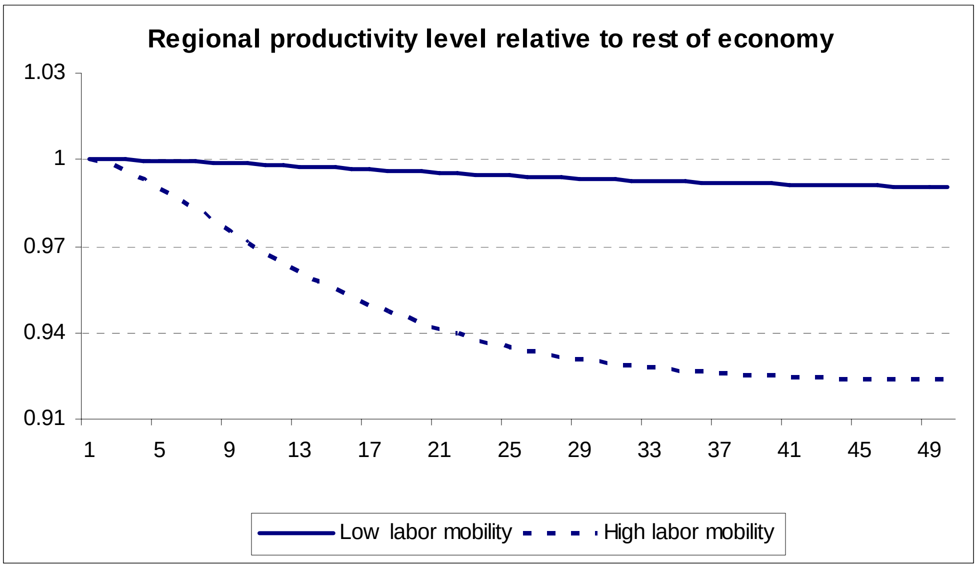

Figure 6. Impact of negative capital shock on relative capital per worker: Low vs. high degree of labor mobility.

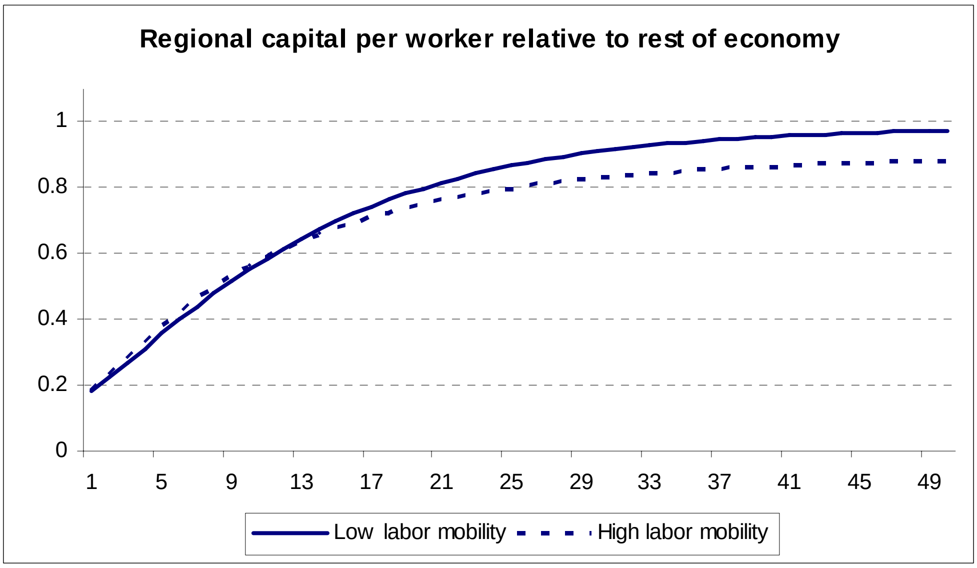

Figure 7. Impact of negative capital shock on relative output per capita when the endogenous productivity response to migration is taken into account: Low vs. high degree of labor mobility.

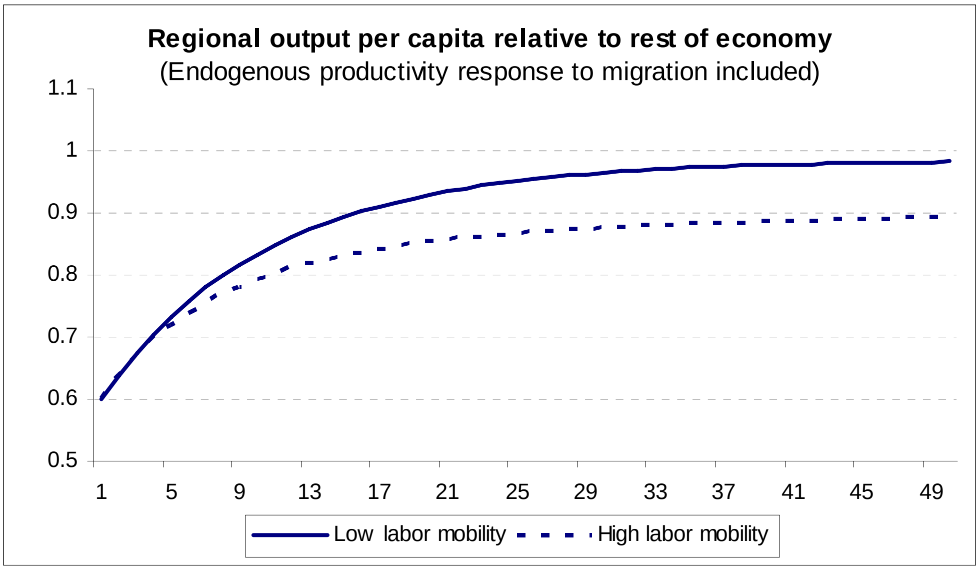

Figure 8. Impact of negative capital shock on relative output per capita when productivity growth is kept exogenous: Low vs. high degree of labor mobility.