The Journal of the Economics of Ageing 1-2 (2013) 35–49

Contents lists available at ScienceDirect

The Journal of the Economics of Ageing

journal homepage: www.elsevier.com/locate/jeoa

Full Length Article

The world's interconnected demographic/fiscal transition

Hans Fehr [a], Sabine Jokisch [a,*], Laurence J. Kotlikoff [b,c]

[a] University of Wuerzburg, Sanderring 2, D-97070 Wuerzburg, Germany
[b] Boston University, Department of Economics, 270 Bay State Road, Boston, MA 02215, United States
[c] National Bureau of Economic Research, United States

ARTICLE INFO

Keywords:
Demographic transition
Overlapping generations (OLG)
Computable general equilibrium models (CGE)
Wage inequality
Asian catchup
Specialization

ABSTRACT

Will incomes of low and high skilled workers continue to diverge? Yes, according to our paper's dynamic, six-good, five-region – U.S., Europe, N.E. Asia (Japan, Korea, Taiwan, Hong Kong), China, and India, general equilibrium, life-cycle model. The model, which endogenizes specialization and features incomplete factor-price equalization, predicts a near doubling of the ratio of high- to low-skilled wages over the century. Increasing wage inequality arises from a traditional source – a rising worldwide relative supply of unskilled labor, reflecting Chinese and Indian productivity catchup. But growing wage inequality can be greatly mitigated if China and India dramatically improve the skill mix of successive cohorts via improved education.

1. Introduction

Rising income inequality is of growing concern in the U.S. and other developed countries. As Piketty and Saez (2003) and Gordon and Dew-Becker (2007) show, the share of income received by the top U.S. income decile rose from 27 percent in the 1960s to roughly 45 percent today.[1] What explains this trend? The answer depends on who one asks. Lawrence (2008) and Gordon and Dew-Becker (2007) point to superstar agglomeration economies and CEO manipulation that has raised income inequality even within the top decile. Bound and Johnson (1992) and Hornstein et al. (2005) trace diverging incomes to skill-biased technical change. Card and DiNardo (2002) and Lemieux (2006) emphasize real reductions in the minimum wage and changes in labor force composition. And Feenstra and Hanson (1996, 1999), Sachs and Shatz (1996), and Wood (1998) point to globalization. Our focus here is the impact of global aging and it's associated fiscal stresses on the evolution of wage inequality. To address this issue, we abstract from other major determinants of inequality, past and future. This is not to deny these forces but rather to isolate the demographic channel which, itself, requires a highly complex framework. The findings of the model we use in this paper should therefore not be taken as definitive predictions of future inequality but rather as informed suggestions of demographics potential, if partial role.

To answer this paper's central question – how will wage inequality progress in the future? – we develop a dynamic, general equilbrium life-cycle model featuring competition among five regions – the U.S., the EMU, Northeast Asia (Japan, Korea, Taiwan, and Hong Kong), China, and India. Each of these regions produces six goods, three of which are traded. The goods are produced with capital and low-, middle-, and high-skilled labor.

The model pays careful attention to region-specific differences in demographics, fiscal conditions, and productivity and incorporates time-varying incomplete specialization and factor price equalization. The model generates more wage inequality over time. Indeed, it generates a near doubling of the ratio of high- to low-skilled wage rates over the century. The source of this rising wage gap arises from a traditional source – an increase in the worldwide relative supply of unskilled labor thanks to Chinese and Indian productivity catchup. In calibrating the model, we assume that the productivity of new cohorts of workers in regions other than the U.S. reaches the U.S. level over time. We set this catch-up period at 10 years for the EMU and Northeast Asia, 15 years for China, and 75 years for India. Once catch-up of new cohorts occurs, it takes a generation for all older worker cohorts in non-U.S. regions to be replaced by younger ones that are as productive as American workers.

New worker cohorts in a given region are assumed to enter the labor force with the same skill mix as older workers in that region. Hence, China and India, whose current work forces are disproportionately low skilled, continue to generate new worker cohorts that are disproportionately low-skilled. But as the productivity of

* Corresponding author. Tel.: +49 7726 3891127.
E-mail addresses: hans.fehr@uni-wuerzburg.de (H. Fehr), sabine.jokisch@gmx.net (S. Jokisch), kotlikoff@bu.edu (L.J. Kotlikoff).

[1] These figures are from Gordon and Dew-Becker (2007). See Hornstein et al. (2005), Eckstein and Nagypal (2004), and Autor et al. (2006, 2008) for additional evidence of rising U.S. wage inequality.

2212-828X/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jeoa.2013.07.002

Chinese and Indian workers, of all three skill types, rises and ultimately reaches the U.S. level, the world experiences a major increase in its relative endowment of low-skilled and, to a lesser extent, middle-skilled workers.

These changes in relative world-wide factor endowments spell increasing wage-rate inequality. In 2005, our model's base year, the wage, measured in efficiency units, of high-skilled workers is 5.9 times higher than that of low-skilled workers. At the end of the century, it's 9.9 times higher. The ratio of the high-skilled wage rate to the middle-skilled wage rate starts at 2.0 in 2005 and ends at 2.3 in 2100.

China's and India's very high saving rates help maintain a healthy world-wide ratio of capital to labor. But this fails to prevent the low-skilled wage rate, measured in efficiency units, from falling in absolute terms – by 35 percent – over the century. In contrast, the high-skilled wage rate rises by 8.3 percent. Middle-skilled workers experience small decreases in their wage rates, again measured in efficiency units. In 2100, they are 6.1 percent lower than in 2005. Shutting down trade with China and India materially improves the prospects of low-skilled workers, but comes at a high economic price to developed regions' economies, whose long-run GDPs are reduced by almost 10 percent. Another casualty is the wage-rate of high-skilled workers, which end up 12 percent lower than occurs with free trade.

In arguing that changes in world wide factor endowments will increasingly undermine the prospects of low- and, to a lesser extent, middle-skilled workers, we do not claim that this troubling aspect of globalization has been the dominant force raising income inequality in recent decades. As Lawrence (2008) and Gordon and Dew-Becker (2007) show, increases in the relative remuneration of the top 1 percent of earners explains much of what has been happening. Their explanations include superstar-agglomeration economies and compensation extraction by top management. Such explanations ring true, and these factors may continue to exert an influence on relative pay. But they are likely to be a side show to the main event, namely the ongoing arrival of hundreds of millions of low- and middle-skilled Chinese and Indian workers increasingly able to compete on equal terms with low- and middle-skilled workers in the developed world.

Increasing wage inequality is not, however, inevitable. If Chinese and Indian education policies limit growth in the world's relative supply of unskilled workers, the exacerbation of wage inequality can, as we show, be substantially mitigated. Indeed, if China and India end up producing workers with the same skill mix as the U.S., relative wages over the century will remain essentially unchanged. Hence, one way for the developed world to improve the lot of its low-skilled workers is to help improve China's and India's educational and on-the-job training systems.[2]

Our calibration of regional skill shares seeks to approximate, albeit very roughly, current wage inequality in the various regions. I.e., it is not based exclusively on college completion rates or other proxies for the population's true underlying skill distribution. How countries' true skill mixes have evolved and will change through time is, itself, a challenging research project. In the U.S., college completion rates have risen from 20 percent in the 1970s to over 30 percent today. But whether this represents true improvement in the degree of young Americans' knowledge and working capacities is an open question. In the limit, it may simply reflect degree-completion inflation – a variant of the well known problem of grade inflation. Moreover, we have no clear knowledge about the degree of past versus current versus future on-the-job training. Certainly, the decline in lifetime employment in the U.S. would militate against the same degree of internal worker training as occurred in the past. In sum, our region-specific handle on current skill distributions and how they may change over the coming decades should be taken for what it is – a sober judgement call tempered by what seems to be reasonable sensitivity analysis. Indeed, our results based on the maintenance of our assumed current skilled distributions are presented as our "base case" not to overly exaggerate this assumption's plausibility, but rather to let us look first at demographic change on its own. Finally, we have opted not to incorporate endogenous human capital formation, as in Heckman et al. (1998), to maintain the models tractability.

Ours is far from the first model to explore the effects of increasing economic integration of developing countries on worldwide production and trade and its impact on wage inequality in a global, general equilibrium setting. For example, Wang and Schuh (2002) analyze the consequences of liberalizing trade policies between the Chinese Economic Area (Taiwan, Hong-Kong and China) and their major trading partners in developed and developing countries. They find that bilateral or multilateral agreements increase economic welfare for the trading partners (with the largest gains for the Chinese Economic Area occuring when the U.S. is included into these agreements) but leads to welfare losses for those countries who are left out. Thus trade liberalization is in the interest of the developed as well as the developing regions. Zhu and Trefler (2005) show that the technological catch-up of developing countries may exacerbate global wage inequality through international trade effects. And they document the empirically relevance of these channels for existing developing countries. However, our approach is different since it assumes common technology and takes into account various demographic and fiscal policy effects, which become increasingly important in the future.

There is a large number of studies that analyze the impact of demographic changes on economic growth and the sustainability of social security systems in computable general equilibrium (CGE) models. Most of them focus on the consequences for national savings rates and the overall economy in industrialized countries, see e.g. Braun et al. (2009) who concentrate their analysis on the savings rate in Japan where the population is currently experiencing a very large aging process. However, the very rapid demographic changes in countries like China inspired studies that focus on the booming developing economies. For example, Wang et al. (2004) analyze the level of the implicit debt of the Chinese pension system and reform proposals to finance the pension system in the light of a rapid aging population.

Since the timing and extent of future demographic changes differ between countries these developments will affect worldwide relative factor endowments and thus international capital flows and world trade patterns. There are several multi-region models that focus on the impact of demographic changes on capital flows between industrialized countries and on their current account balances, see e.g. Domeij and Flodén (2006) or Fehr et al. (2005). They hardly pay any attention on how China, India, and other developing countries in eastern Asia will influence economic developments in the industrialized world. But as Fehr et al. (2007) show China with its high growth and savings rates has a major effect on world capital markets and therefore may provide capital to support the aging industrialized economies.

How demographic changes affect economic growth in the developing regions, worldwide relative factor supplies and thus world wide trade patterns has more or less been neglected in these studies. However, Wei and Hao (2010) and Bloom et al. (2010) find in their empirical analysis that past demographic developments especially the fertility decline helped to improve the worker-to-population ratio and thus to boost economic growth in China and India. Bloom et al. (2010) point out that this effect was more pronounced in China but it will help India in the future. They conclude

[2] Certainly, China has been taking a very active role at the government level in promoting higher education with its fast-track program of building new universities.

that changes in the demographic parameters in the developing regions will indeed affect worldwide endowments in the future and that due to the size of their populations China and India will have the potential to become dominant forces in the world economy.

Thus there are many different interdependent factors that will influence worldwide production structures, trade patterns and thus economic growth in the future. In this paper we therefore introduce a new CGE model that captures these interdependent demographic, fiscal, and economic transition paths of industrialized as well as developing Asian countries. Our study builds on earlier work of Fehr et al. (2007), which excluded India, Taiwan, Hong Kong, and Korea. It also posited just one good produced with capital and a one type of labor. This single labor input comprised the sum of effective units of labor supplied by workers with low, middle, and high labor-efficiency coefficients. The basic message of this earlier work is that high-saving developing regions can help low-saving developed countries maintain a high level of capital intensivity along their demographic transition paths. What that study was unable to examine, however, was how badly low-wage workers might be hurt by global trade and whether the harm to low-wage workers would worsen over time.

In order to study the impact of globalization on the income distribution, we introduce imperfect substitution of skill-types in production and distinguish various production sectors which produce (with different technologies) traded and non-traded private and public consumption goods and an investment good. As before, we incorporate a rich demographic structure and model fiscal institutions in detail. Agents give birth to fractions of children at each child-bearing age, with future age-specific birth rates closely tracking government projections. After age 67, agents die randomly based on current and projected mortality probabilities. Immigration is treated as exogenous, again based on current and forecasted patterns. Each region has progressive tax and transfer benefit systems. By modifying these systems, we can study how fiscal policies alter international, intergeneration, and intrageneration distributions of welfare.

The mechanism by which wage inequality is transmitted across borders in our model is standard, namely changes in relative prices of traded products inducing changes in relative factor prices. But with five regions there is no guarantee of incomplete specialization and factor price equalization in all periods. Our model accommodates specialization on a period-specific basis under which some factor prices are equalized across some, but not necessarily all regions. And we provide a method of determining the changing pattern of specialization as part of the Auerbach-Kotlikoff (1987) iterative simulation solution technique for solving for life-cycle economies' transition paths. We also present results in which factor price equalization holds at all times across all regions. To effect this outcome we assume that firms in one country can hire labor abroad and use that labor remotely. This provides a synthetic form of labor mobility in which nationals from one country become workers in another without immigrating. Real life examples here include call centers of U.S. companies manned by Indians and computer programming done jointly by U.S. and Indian engineers for U.S. companies.

Sections 2 and 3 describe, in turn, the model, calibration, and data sources. Section 4 presents baseline and alternative policy results, including shutting down trade with China and India and changing Chinese and Indian education policy, and Section 5 summarizes key findings and concludes.

2. Model

We start with demographics and then clarify household economic behavior, firm behavior, the macroeconomic equilibrium, and fiscal institutions.

2.1. Demographics

Agents in each region live at most to age 90. Consequently, there are 91 generations with surviving members at any point in time. The life cycle of a representative agent is described in Fig. 1. Between ages 0 and 20 our agents are non-working children supported by their parents. At 21 our agents go to work and become individual households. Between ages 23 and 45 our agents give birth each year to fractions of children. An agent's first-born children (fractions of children) leave home when the parents are age 43 and the last-born leave when the agents are age 66. Our agents die between ages 68 and 90. The probability of death is 1 at age 91. Children always outlive their parents, meaning that parents always outlive grandparents.[3]

We denote the population vector for year t by $N(a,t,s,k)$, where $a = 1,\dots,90$, $s = 23,\dots,45$, $k = 1,2,3$. The term s references the age of the parent at the time of birth of agents age a and k is the skill class. Since agents younger than 23 have no children and those over 65 have only adult children, the total number of children of an agent age a with skill k in year t $KID(a,t,k) = 0$ for $0 \leqslant a \leqslant 22$ and $66 \leqslant a \leqslant 90$. Agents between these ages have children. Take, for example, a 30 year-old agent. Such an agent has children who were born in the years since she/he was 23. In year t, these children are between age 0 and 7. The $KID(\cdot)$-function sums the total number of children of the respective parent skill-class generation and divides it by the total number of parents of age a in year t who belong to skill k. This function takes into account that the family's age structure will change over time due to changes over time in age-specific fertility.[4]

Immigration is only included into our model to match population projections. For this reason, our treatment of immigration is simple.[5] In each year new immigrants in each skill and age group arrive with the same number and age distribution of children and the same level of assets as natives of the identical skill and age. Once they join a native cohort, they experience the same future age-specific fertility and mortality rates as native-born agents.

2.2. The household sector

The model's preference structure is represented by a time-separable, nested, CES utility function. Remaining lifetime utility $U(l,t,s,k)$ of a generation age l at time t whose parents were age s at their time of birth and who belong to skill-class k takes the form

$$U(l,t,s,k) = V(l,t,s,k) + H(l,t,s,k), \tag{1}$$

where $V(l,t,s,k)$ records the agent's utility from her/his own goods and leisure consumption and $H(l,t,s,k)$ denotes the agent's utility from the consumption of her/his children. In the following, the indices s and k are substituted by $\cdot$ for simplicity whenever possible. The two sub-utility functions are defined as follows:

$$V(l,t,\cdot) = \frac{1}{1-\frac{1}{\gamma}} \sum_{a=l}^{90} \left(\frac{1}{1+\delta}\right)^{a-l} P(a,i) \left[\bar{c}(a,i,\cdot)^{1-\frac{1}{\rho}} + \varepsilon \ell(a,i,\cdot)^{1-\frac{1}{\rho}}\right]^{\frac{1-\frac{1}{\gamma}}{1-\frac{1}{\rho}}} \tag{2}$$

$$H(l,t,\cdot) = \frac{1}{1-\frac{1}{\gamma}} \sum_{a=l}^{90} \left(\frac{1}{1+\delta}\right)^{a-l} P(a,i) KID(a,i,k) \bar{c}_K(a,i,\cdot)^{1-\frac{1}{\gamma}}, \tag{3}$$

where

[3] If a parent reaches age 90, his or her oldest children will be 67. These are children who were born when the parent was age 23.

[4] This approach permits the distribution of births by the ages of parents to change over time – an important improvement relative to the birthing process stipulated in Kotlikoff et al. (2007).

[5] Specifically, we do not consider endogenous migration decisions, neither return-migration and assume that all migrants come from the rest of the world which is not included in the model.

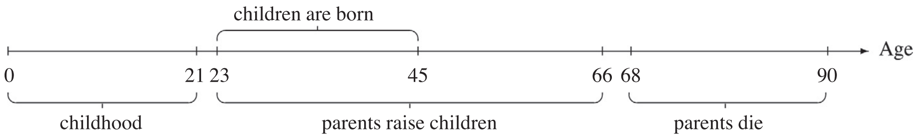

Fig. 1. The individual life-cycle.

$$\bar{c}(a,i,\cdot) = \left[\sum_{j\in G_c} \kappa(j,a)c(j,a,i,\cdot)^{\varphi}\right]^{\frac{1}{\varphi}} \tag{4}$$

denotes the aggregate private consumption good, while $c(j,a,i,\cdot)$ and $\ell(a,i,\cdot)$ denote private consumption of goods j and leisure respectively, G_c defines the set of all private consumption goods, $i = t + a - l$ and $\kappa(j,a)$ defines the consumption share of good j at age a, with $\sum_{j\in G_c}\kappa(j,a) = 1$. In permitting these shares to vary with age, our model can accommodate age-related changes in, for example, demand for medical services. The elasticity of substitution between different consumption goods j is denoted by ω, where $\varphi = 1 - \frac{1}{\omega}$. The price index $\bar{p}(a,i)$ for the aggregate consumption good $\bar{c}(a,i,\cdot)$ at age a in year i is

$$\bar{p}(a,i) = \left[\sum_{j\in G_c} \kappa(j,a)^{\omega} p(j,i)^{1-\omega}\right]^{\frac{1}{1-\omega}}, \tag{5}$$

where $p(j,i)$ defines the consumer price of good j in year i.[6] The children's aggregate consumption of skill-class k parents who are age a in period i and whose parents were age s at the time of their birth is defined as $\bar{c}_K(a,i,\cdot)$, and the number of children supported by parents age a is $KID(a,i,k)$. We assume that parents apply the same consumption shares $\kappa(j,a)$ and substitution elasticities ω when they decide upon their children's consumption $c_K(j,a,i,\cdot)$.

Since lifespan is uncertain, the utility of consumption in future periods is weighted by the survival probability of reaching age a in year i

$$P(a,i) = \prod_{u=l}^{a}[1 - d(u, u - a + i)], \tag{6}$$

which is determined by multiplying the conditional survival probabilities from year t (when the agent's age is l) through year i. Note that $d(l,t)$ is the mortality probability of an agent age l in year t. The parameters δ, ρ, ε and γ represent the rate of time preference, the intratemporal elasticity of substitution between consumption and leisure, the leisure preference parameter, and the intertemporal elasticity of substitution between consumption and leisure, respectively.

Given the asset endowment a $(l,t,\cdot)$ of the agent in year t, the lifetime budget constraint is defined by:

$$\begin{aligned} \mathrm{a}(l+1,t+1,\cdot) = {} & [\mathrm{a}(l,t,\cdot) + I(l,t,\cdot)](1+r(t)) + w(k,t)E(l,t) \\ & \times [h(l,t) - \ell(l,t,\cdot)] - T(l,t,\cdot) - \bar{p}(l,t)[\bar{c}(l,t,\cdot) \\ & + KID(l,t,k)\bar{c}_K(l,t,\cdot)], \end{aligned} \tag{7}$$

where $r(t)$ is the pre-tax return, $I(l,t,\cdot)$ denotes inheritances received in year t. The budget incorporates our assumption that annuity markets are not operative. Instead, agents who die leave unintended bequests to their children. These children share equally in their parents' estates as well as in all the estates of other parents in the same skill group who die in that year. Thus, 50 year-olds in year t whose parents were age 28 when they were born will inherit an equal share of all the assets left by 78 year-old decedents in year t, where the total inheritors include all children of these decedents, not just those age 50. To be precise, the inheritance of agents age l in year t whose parents were age s at their birth is given by:

$$I(l,t,s,k) = \frac{d(l+s,t)\bar{A}(l+s,t,k)}{\sum_{u=23}^{45} N(l+s-u,t,u,k)}. \tag{8}$$

The numerator in this ratio measures the aggregate assets of skill-class k parents who die in year t at age $l+s$. The denominator measures the total number of children of these parents who are between ages $l+s-45$ and $l+s-23$ in year t. The receipt of inheritances requires us to distinguish members of each cohort according to the ages of their parents at the time the cohort members were born. The parents' ages at death determine when the children receive their inheritances. While the oldest children (born when their parents are age 23) receive their inheritances between ages 45 and 67, the youngest (born when their parents are age 45) receive their inheritances between ages 23 and 45.[7]

As in Altig et al. (2001) and Kotlikoff et al. (2007), we model technical progress as permitting successive generations to use time more effectively, whether in working or enjoying leisure. We implement this assumption by having the time endowment of successive generations in each region grow at the common rate λ. Denote $h(a,i)$ the time endowment of an agent age a at time i, then

$$h(a,i) = (1+\lambda)h(a,i-1). \tag{9}$$

This treatment of technical change ensures eventual convergence of the economy to a long-run steady state. Other formulations of technical change, such as making it labor-augmenting, preclude a steady state given the model's preferences. And our iterative method for determining the model's equilibrium transition path requires the terminal conditions provided by the economy's long-run steady state.[8]

Gross labor income of an agent in year i is derived as the product of her labor supply and wage rate. The latter is the product of the skill-specific wage rate $w(k,i)$ in year i and age- and year-specific productivity per time-unit $E(a,i)$.

Net taxes, $T(l,t,\cdot)$, include consumption, capital income, and progressive wage taxes as well as social security contributions net of pension, disability, and health benefits received in the form of transfer payments. Given the assumed ceiling on payroll tax contributions, payroll tax rates, both average and marginal, differ across agents. Each agent's pension benefits depend on her pre-retirement earnings history, while healthcare and disability transfers are provided on a per capita basis.

Given price indices $\bar{p}(a,i)$, interest rates $r(i)$, and wages $w(k,i)$, agents maximize utility (1) subject to the intertemporal budget constraint (7) and the constraint that leisure in each period not exceeds the time endowment (i.e. $\ell(l,t,\cdot) \leqslant h(l,t)$). They do this by choosing their leisure and consumption demands, i.e.,

[6] Note that the price index is independent of skill class since we assume identical consumption shares in each skill class.

[7] Note that in providing children each year with the average inheritance left by all parents of the same age as their own parents, we avoid introducing uncertainty with respect to the amount of inheritance received each year. Hence, our model incorporates idiosyncratic uncertainty about one's date of death, but certainty with respect to what one inherits.

[8] Note that assuming a higher rate of technical progress is isomorphic to assuming a higher rate of fertility; i.e., having more people is equivalent to having fewer people who each have more time. Since fertility rates don't enter into production functions, we circumvent the problem of steady-state incompatibility.

$\ell(l,t,\cdot), \bar{c}(a,i,\cdot)$ and $\bar{c}_K(a,i,\cdot)$. Demands for specific goods $j \in G_c$ are, then, derived from

$$c(j,a,i,\cdot) = \left(\frac{\kappa(j,a)}{p(j,i)}\right)^{\omega} \bar{p}(a,i)^{\omega}\bar{c}(a,i,\cdot). \tag{10}$$

Given individual consumption and leisure, agents' asset levels are derived from (7). Aggregate values of assets, private consumption goods, and labor supply obey

$$A(t+1) = \sum_{k=1}^{3}\sum_{a=21}^{90}\underbrace{\sum_{s=23}^{45} a(a+1,t+1,s,k)N(a,t,s,k)}_{\bar{A}(a+1,t+1,k)}, \tag{11}$$

$$C(j,t) = \sum_{k=1}^{3}\sum_{a=21}^{90}\sum_{s=23}^{45}[c(j,a,t,s,k) + KID(a,t,k)c_K(j,a,t,s,k)]N(a,t,s,k), \tag{12}$$

$$L^s(k,t) = \sum_{a=21}^{90}\sum_{s=23}^{45} E(a,t)[h(a,t) - \ell(a,t,s,k)]N(a,t,s,k). \tag{13}$$

Since households die at the beginning of each period, we aggregate across all agents alive at the end of the prior period to compute $\bar{A}(a+1,t+1,k)$, which is used in the calculation of bequests (see (8)). Total assets of agents alive at the end of period $t+1$ satisfies

$$\mathcal{A}(t+1) = \sum_{k=1}^{3}\sum_{a=21}^{90}\sum_{s=23}^{45} a(a,t+1,s,k)N(a,t+1,s,k), \tag{14}$$

which includes the assets and numbers of period $t+1$ immigrants.

2.3. The production sector

Besides private consumption goods, each region also produces a public consumption and an investment good, the index set of all goods produced is denoted by G. Aggregate output $Y(j,t)$ of each good j is produced via a Cobb–Douglas technology that uses capital $K(j,t)$ and skill-specific labor $L(k,j,t)$, i.e.,

$$Y(j,t) = \phi K(j,t)^{\alpha(j)}\left[\prod_{k=1}^{3} L(k,j,t)^{\beta(k,j)}\right]^{1-\alpha(j)}, \quad \text{for } j \in G \tag{15}$$

where $\sum_{k=1}^{3}\beta(k,j) = 1$. The parameter ϕ references total factor productivity, and $\alpha(j)$ and $\beta(k,j)$ denote capital's share and the share of skill-specific labor inputs in production, respectively.

The assumption of constant returns to scale is standard and required for the ultimate convergence to a steady state, which is needed to solve our model's transition path. But the assumption is also strong. Entertaining increasing returns to scale, which China, at least, appears to be exploiting in its development success must, unfortunately, remain a goal for future work.

Profit maximization requires

$$[r(t) + \delta_K]K(j,t) = \alpha(j)q(j,t)Y(j,t) \tag{16}$$

$$w(k,t)L(k,j,t) = [1-\alpha(j)]\beta(k,j)q(j,t)Y(j,t), \tag{17}$$

where δ_K is the depreciation rate and $q(j,t)$ denotes the producer price of good j in t.

2.4. The government sector

Each region's government issues additional debt, $\Delta B(t)$, and collects taxes to finance outlays for general government expenditures $q(g,t)C(g,t)$ (with $q(g,t)$ and $C(g,t)$ defining producer price and quantity, respectively), general-revenue financed social benefits $SB(t)$ (i.e. pension, healthcare, and disability benefits) and interest on existing debt:

$$\Delta B(t) + \sum_{k=1}^{3}\sum_{a=21}^{90}\sum_{s=23}^{45} T(a,t,s,k)N(a,t,s,k) = q(g,t)C(g,t) + \varrho SB(t) + r(t)B(t), \tag{18}$$

where ϱ denotes the share of these transfer payments that are financed by general revenues.

The progressivity of wage taxation is modelled after Auerbach and Kotlikoff (1987), with marginal wage tax rates rising linearly with the wage-tax base. $PY(t)$ defines the aggregate payroll-tax base, which differs from total labor earnings due to the ceiling on taxable wages. This ceiling is fixed at 290, 200, 150, 300, and 300 percent of average income in the U.S., EMU, NEA, China, and India, respectively. Average employer plus employee payroll tax rates $\hat{\tau}^p(t)$ for the pension, healthcare, and disability transfer programs are determined based on each region's transfer-program-specific budget, taking into account general revenue finance, i.e.

$$\hat{\tau}^p(t)PY(t) = (1-\varrho)SB(t), \tag{19}$$

Due to contribution ceilings, individual payroll-tax rates can differ from the average payroll tax rate. Above the contribution ceiling, marginal social security contributions are zero and average social security contributions fall with the agent's income. To accommodate this non-convexity in the budget constraint, we assume that the highest earnings class in each region pays payroll taxes up to the relevant ceilings, but faces no payroll taxation at the margin.

If an agent retired in year i at the exogenously set retirement age $\bar{a}(i)$, her pension benefit $Pen(a,t,\cdot)$ in year $t \geqslant i$ when she is age $a \geqslant \bar{a}(i)$ is assumed to depend linearly on her average earnings during her working life $\bar{W}(i,\cdot)$:

$$Pen(a,t,\cdot) = v_0 + v_1 \times \overline{W}(i,\cdot). \tag{20}$$

The region-specific parameters v_0, v_1 for the U.S., the EMU and NEA were chosen to match replacement rates reported in OECD (2007b). In China and India, only a fraction of public employees are covered by the public pension system. But spending on civil service pensions in China and India amounts to 2–3 percent of GDP (see World Bank, 2005). Since we do not distinguish between covered and non-covered employment in our model, we assume a pension-replacement rate of 40 percent of average pre-retirement earnings. The rate is far too low for covered employees and far too high for non-covered employees, but it results in realistic aggregate pension expenditures in the two countries.

General government expenditures $q(g,t)C(g,t)$ consist of government purchases of goods and services, including educational expenditures and health outlays. Over the transition, we keep age-specific per capita purchases fixed in efficiency terms so that aggregate expenditures adjust due to population dynamics.[9]

Age-specific health outlays per capita also grow with GDP per capita. However, in the U.S., EMU, and Japan we assume an additional growth rate of 2.0 percent per year during the first 20 years of the transition and of 1.0 percent between 2025 and 2035.[10] In China and India, age-specific healthcare outlays per capita are assumed to grow at a faster pace: During the first 40 years of the transition there is an additional annual growth rate of four percent. Note that while we treat 80 percent of health benefits as government consumption and 20 percent as fungible transfers to households, disability benefits are modeled exclusively as fungible transfers to households.

During the transition, the governments in the U.S., EMU, NEA and India maintain their initial debt-to-output ratios over time. In these regions we keep the ratio of wage-tax to consumption-tax revenue fixed each year and balance the government's annual budget (18) by adjusting the intercept in our linear equation determining the average wage-tax rate as well as the consumption-tax

[9] Implicitly, we assume that additive separability of preferences in public consumption goods. But since the latter is constant during the transition, we can omit it in (1).

[10] As shown in Hagist and Kotlikoff (2009), this is a rather conservative assumption concerning future growth in benefit levels.

rate. In the case of China, we fix the initial wage and consumption tax rates and adjust government's debt to balance the annual budget during the first 10 years of the transition. After this period we adopt the same policy as in the other regions, i.e. maintaining the debt-to-output ratio over time and endogenously adjusting the wage and consumption tax rates.

2.5. Computational approaches: offshoring vs. regional-specific factor prices

To compute the world economy's perfect-foresight general equilibrium transition path, we normalize the producer price of the investment good to unity and start with initial guesses of the equilibrium factor prices and product prices of consumption goods. Given these prices we can determine consumption demands as well as labor and asset supplies for each region. Summing up demand of traded goods and the difference between future and current assets (net of public debt) across regions determines the required world output for traded goods and the investment good. Next we determine the factor demands in the non-traded goods sectors and derive the remaining factor supplies for traded goods in each region. Using the fact that world factor supplies have to be equal to world factor demands for traded goods, we can update factor prices and producer prices and compute region-specific shares of production for each traded good. Our algorithm iterates until the time paths of interest and wage rates converge to a fixed point and supplies for each good equals its demand. We give our economy 300 years to reach to a steady state. In fact, our model reaches a steady state to many decimal places decades prior to year 300. It also converges very tightly around the equilibrium transition path.

However, nothing precludes our model calculating negative values for the region-specific output shares of traded goods. Negative values are, of course, infeasible and indicative of specialization. We compare two different adjustment mechanisms to deal with specialization. In the first scenario we assume that domestic firms employ offshore labor to participate in their domestic production processes via internet and telephone until the negative output shares have disappeared. Of course, in this "'offshoring" scenario factor price equalization across regions will be restored despite the fact that some goods are not produced exclusively by inputs that are resident in a country. In the second scenario we do not permit offshoring. Instead, we compute the pattern of specialization that occurs each period and the resulting period-specific pattern of incomplete factor-price equalization.[11]

3. Calibration

The following sections highlight our model's calibration. Fehr et al. (2008) provide a detailed discussion of our population projections and the specification of production, preference and policy parameters.

3.1. Population projections

Our model has a highly detailed demographic structure that changes over time on a region-specific basis.[12] The main data source for our population data is the medium variant of the United Nations population projections (UNPD, 2007) as well as the national population statistics provided by the Statistical Office of Taiwan (CEPD, 2007).

To determine the evolution of the population in each region over time, we applied region-, age-, and year-specific mortality and fertility rates to the cohorts alive in year 2000 as well as to their children as they reach their ages of fertility and mortality. The exogenous current and future mortality and fertility rates follow the medium variant of the United Nations population projection (UNPD, 2007) until 2050. Afterwards, fertility rates are endogenously adjusted in line with zero population growth and a stable population age structure.

Each cohort in our model is split into three skill classes k. We assume that 15 percent of each cohort belong to the lowest skill class, 30 percent to the top skill class, and the remaining 55 percent to the middle skill class in the U.S., EMU and NEA. This is in line with figures on educational attainment from Barro and Lee (2001) for the three-region agglomerate as well as with the latest figures for the U.S. from the U.S. Census Bureau (2008). In China and India, we assume that 22 percent of the overall population belong to the lowest, 25 percent to the top skill class, and 53 percent to the middle. At first glance, the small value for the share of low-skilled workers in China and India may seem surprising. Indeed, according to the data of Barro and Lee (2001), 44 percent of the population aged 15 and over in India and 18 percent in China have received no formal education. On the other hand, these shares produce relative wages for the three income classes in the initial year that coincide with OECD (2008) region-specific earnings-dispersion data.

Table 1 compares the actual and simulated population projections.

3.2. Production, preference and policy parameters

Our aggregation of goods into four consumption goods (services, housing, low tech, and high tech), an investment good, and a public good is based on the March 2007 release of the EU-KLEMS database (see Timmer et al., 2007). Given this sectoral aggregation, we computed the capital income shares as well as the skill-specific labor shares from the 2004 (SIC based) U.S. data as reported in Table 2. As one would expect, capital income shares are especially high in the housing sector; they are especially low in the private service and public goods sectors. With the exception of housing our capital shares accord closely with the sector capital shares reported in Valentinyi and Herrendorf (2008). The low-tech consumption good and housing sectors have the highest shares of low-skilled labor; the high-tech consumption good sector, the non-housing services sector, and the public good sector have the highest share of high-skilled labor. Finally, the depreciation rate is set at the same rate for all countries.

Table 3 reports values of preference and policy parameters. The time-preference rate was set to match the model's 2005 ratios of private consumption to GDP to the region-specific values in the U.S., EMU, and NEA[13] reported in European Commission (2008). We keep these rates fixed during the transition path except for China where we assume a gradual increase to a time preference rate of 0.02 during the first 25 years of the transition. This reflects our view that the Chinese are saving at such a high rate in part because of limited capacity to insure and that government and private insurance institutions will evolve over time.[14] The intertemporal elasticity of substitution, the elasticity of substitution between consumption and leisure, and the leisure preference parameters are taken from

[11] A detailed description how to implement these two adjustment mechanisms numerically is available from the authors upon request.

[12] Although the economic model starts in year 2005, we chose year 2000 as the initial year for population projections due to data availability.

[13] Note that all macroeconomic values for NEA are compared to official data reported for Japan.

[14] The source of China's very high national saving rate is not fully understood. It may reflect a more moderate private rate of saving than assumed here and more government saving. The national income accounts data for China may not, in this regard, be fully reliable. In Fehr et al. (2013) we have explored higher Chinese time preference and larger government saving with no material change in our findings.

Table 1
Comparing actual and simulated population projections.

Country	U.S.		EMU		NEA		China		India	
Year	2005	2050	2005	2050	2005	2050	2005	2050	2005	2050
Fertility rate										
Model	2.08	1.85	1.49	1.82	1.53	1.75	1.64	1.85	2.99	1.85
Official	2.05	1.85	1.50	1.85	1.53	1.73	1.73	1.85	2.81	1.85
Life expectancy at birth										
Model	81.9	83.8	82.4	84.6	84.2	87.3	76.2	80.2	63.9	75.3
Official	78.2	83.1	79.7	84.3	81.2	86.7	73.0	79.3	64.7	75.6
Total population (in millions)										
Model	293.9	403.6	309.5	308.3	205.4	181.4	1228.1	1401.5	1129.9	1643.9
Official	299.8	402.4	312.2	312.9	205.6	172.6	1313.0	1408.8	1134.4	1658.3
Age structure (in percent of total population)										
0–15 Years										
Model	20.7	17.8	16.1	15.0	14.6	13.7	21.6	16.3	33.2	18.2
Official	20.8	17.3	15.6	14.5	15.5	10.7	21.6	15.3	33.0	18.2
15–64 Years										
Model	67.2	62.0	67.1	57.5	65.8	53.1	71.8	61.6	62.4	66.1
Official	66.9	61.7	66.8	55.9	68.5	52.6	70.7	61.0	62.0	67.3
65–90 Years										
Model	12.1	20.1	16.8	27.5	19.5	33.2	6.6	22.0	4.4	15.7
Official	12.3	21.0	17.6	29.6	16.0	36.7	7.7	23.7	5.0	14.5

Table 2
Production technology parameters.

	Symbol	Services	Housing	Low tech	High tech	Investment Good	Public Good
Capital share in production	$\alpha(j)$	0.26	0.57	0.44	0.41	0.35	0.26
Share of specific labor inputs	$\beta(k,j)$						
Low-skill ($k = 1$)		0.08	0.11	0.15	0.03	0.06	0.02
Medium-skill ($k = 2$)		0.57	0.62	0.58	0.38	0.57	0.39
High-skill ($k = 3$)		0.35	0.27	0.27	0.59	0.37	0.59
Technology coefficient	ϕ			4.29[a]			
Depreciation rate	δ_K			0.075			

[a] Normalizes U.S. low-skilled wages in initial year to unity.

Table 3
Preference, productivity and policy parameters.

	Symbol	U.S.	EMU	NEA	China	India
Time preference rate	δ	0.032	−0.002	0.028	−0.070	0.056
Intertemporal elasticity of substitution	γ			0.25		
Intratemporal elasticity of substitution						
-between consumption and leisure	ρ			0.4		
-between consumption goods	ω			1.1		
Leisure preference parameter	ε			1.5		
Consumption shares of goods j	$\kappa(j,a)$	Services	Housing	Low tech	High tech	
$a < 25$		0.04	0.36	0.19	0.41	
$25 \leqslant a \leqslant 34$		0.06	0.40	0.17	0.37	
$35 \leqslant a \leqslant 44$		0.07	0.40	0.18	0.35	
$45 \leqslant a \leqslant 54$		0.08	0.38	0.17	0.37	
$55 \leqslant a \leqslant 64$		0.11	0.38	0.17	0.34	
$65 \leqslant a \leqslant 74$		0.16	0.38	0.16	0.30	
$a \geqslant 75$		0.21	0.40	0.15	0.24	
Shift parameter for productivity	ξ	1.00	0.65	0.50	0.018	0.01
Technical progress	λ			0.01		
Capital tax rate (in %)	τ^r	11.0	14.0	8.0	3.0	3.0
Debt (in % of national income)	B/Y	43.4	50.3	70.0	23.5	60.0
Age of retirement	$\bar{a}$	63	60	60	60	60

Kotlikoff et al. (2007). The elasticity of substitution between consumption goods was chosen to generate a pattern of demand that accords with U.S. consumption data. The age-specific weights of the different consumption goods in the utility function are derived from U.S. Department of Labor (2007), where we aggregated the different consumption goods reported there according to our Table 2 classification. Note that the consumption shares vary significantly with age, with housing's share rising considerably with age.

Our model requires an initial distribution of assets by age and income class for each region. These profiles are adopted from each region's data.[15] We scaled these age-asset profiles to reach a wealth-output ratio of 3.0 in the U.S., 2.8 in EMU, 2.5 in NEA, 1.0 in China and 0.75 in India.

The age- and year-specific productivity profile of an age a individual in period i

$$E(a,i) = \xi(i)e^{4.47+0.033(a-20)-0.00057(a-20)^2}(1+\lambda)^{a-21}$$

is taken – apart from the term $\xi(i)$ – from Auerbach and Kotlikoff (1987). Note that the higher is the rate of technological change, λ, the steeper is the age-ability profile. This captures the role of technical progress in influencing not just the level, but also the shape of longitudinal age-earnings profiles. We normalize the labor productivity parameter – ξ– at 1 for the U.S. and set the initial values of this parameter for the other four regions to match the 2005 relative values of GDP. Thus it's initially set to 0.65 in the EMU, 0.5 in NEA, 0.018 in China, and 0.01 in India. In the non-U.S. region, this parameter is gradually raised to 1.0 (the U.S. value) for each successive cohort of new worker cohorts. For the EMU and NEA we assume these adjustments occurs over the 10 years between 2005 and 2015. For China we assume it takes 15 years. And for India, we assume 75 years. This assumption concerning India is in line with Bosworth and Collins (2008) who found that during the last four decades India made little progress in increasing even elementary educational attainment. Once this phase-in period is complete, it takes another 40 years until all cohorts of workers in the non-U.S. regions have the same value, namely 1, of ξ entering in the determination of their labor productivity. Although different cohorts in the same as well as in different regions start out with different productivity levels, they each experience the same growth in their productivity as they age.

4. Findings

4.1. Initial equilibrium and baseline path

This section reports our baseline transition path findings. We start in Table 4 by comparing simulated with observed 2005 macro variables. The official GDP figures presented on the right side of Table 4 come from European Commission (2007, 2008), and, for India, OECD (2007d). The model's values for consumption, government purchases, and investment come very close to their official counterparts. Note especially that our model matches the very high rate of private consumption in the U.S. and very high rates of domestic investment in China and India. The model also does very well in matching relative GDP levels as reported by the World Bank (2007). The calculation of public goods is based, in part, on OECD (2005, 2006) data on education outlays and, in part, on the assumption that 80 percent of government health expenditures is government consumption. We also tried to reach a realistic tax structure as per official data. As already explained above, we fixed the wage and consumption tax rates in China during the first 10 years of the transition and adjusted public debt endogenously. Afterward 2019 we hold public debt fixed relative to GDP and wage and consumption tax rates are adjusted annually to balance government's budget. This permits China to continue pursuing, for a number of years, its clear policy of limiting private-sector consumption by extracting significant resources from the private sector and investing them. In our model, the Chinese debt is negative so the government runs a surplus, which it invests in the domestic economy.

Our model's trade balances agree in sign, but not value, with actual values. But given that our model excludes regions outside of our five, one should probably not expect too much concurrence with respect to trade balances or current accounts. Outlays of the social security systems were calibrated to yield the official values from OECD (2007a,b,c). The official contribution rates for pensions, health-care and disability were taken from SSA (2006) for the U.S. and from SSA (2007) for NEA (Japan), China and India.[16] Obviously, our pension and health insurance contribution rates in China and India deviate from official figures. Our model assumes that all households in all regions are covered by the government's pension system whereas only about 23 percent of the total workforce in China and India are so covered (Deutsche Bank Research, 2006).

Table 5 reports the baseline path of GDP for the five regions as well as the evolution of domestic capital stocks, labor demands, and average effective wage tax rates. All indexes for the five regions are expressed relative to year-2005 values in the U.S. The first point of interest is the growth of the U.S. economy relative to the EMU and NEA economies. U.S. GDP expands by a factor of 4.6 over the century, whereas EMU GDP expands by a factor of only 3.1, and NEA GDP expands by a factor of only 2.6. These differences reflect, in large part, demographic differences across the regions, particularly the absolute population decline in NEA.

China's GDP, in contrast, starts at 19 percent of the U.S. value, but overtakes the U.S. by 2020. But once China's productivity levels reach U.S. values, its growth slows. Consequently, by 2100, China's GDP is only 1.8 times the U.S. level. The results for India are also quite interesting. Thanks to India's slower productivity growth, its growth explosion occurs in the second half of the century. But by century's end, India's GDP is 2.6 times U.S. GDP and 1.4 times China's. Together, China and India account for 4.4 times U.S. GDP in 2100, and U.S. GDP, which accounts for 38.3 percent of total 5-region GDP in 2005, accounts for only 16.1 percent in 2100. In short, the U.S. becomes a small player in the developed world.

The growth of output can be explained, in part, by the growth of inputs. Table 5 shows that the capital stock in each region grows almost in lockstep with GDP in each region. Equilibrium labor demand (and supply) rise both because of technical progress (the expansion of effective time available to successive cohorts) and changes in labor supply. In the other regions, this growth also reflects changes in labor productivity as successive new cohorts of workers gradually attain U.S. productivity levels. As a consequence, effective labor expands in Table 5 very rapidly in China between 2005 and 2030 and in India between 2050 and 2100.

Table 6 examines how components of GDP evolve in the five regions. Over the first 30 years, the U.S. runs sizeable annual trade deficits as it imports capital from China, whose very high saving rate leads to considerable asset accumulation and large trade surpluses. Ultimately, the returns from these investments in the U.S. must be repatriated, which explains why both the U.S. trade deficit and the Chinese trade surplus decline after 2050.

The patterns of wealth accumulation in the U.S. and China over time are also documented by the changes in net foreign assets. Whereas interest on net foreign debt reduces the current account in the U.S. to 2.8 percent of GDP in 2100, interest income from abroad amounts to 28 percent of GDP in China in that year. Table 6 shows that trade and current account deficits can be very sizeable for decades before they reverse their sign and that their pattern is not easily forecast. There are a host of complex, interconnected

[15] Data on Japanese net worth were provided by Statistics Bureau Japan (2002) and are used for the profiles in NEA, China and India. The European profiles were adjusted to German data provided by Reinhold Schnabel. U.S. data were derived from the 1998 Survey of Consumer Finances reported in Kennickell et al. (2000). The age-asset profiles for the specific income classes were scaled according to relative wealth in a steady-state run of our model.

[16] The official tax revenue data come from European Commission (2008) for U.S., EMU and NEA (Japan), from OECD (2002) for China, and from Poirson (2006) for India.

Table 4
The year 2005 of the baseline path.

	Model					Official				
	U.S.	EMU	NEA	China	India	U.S.	EMU	NEA	China	India
Gross Domestic Product[a]										
Private consumption	70.7	57.6	57.3	38.5	58.6	70.4	57.4	57.0	38.0	58.5
Government purchases of goods and services	15.9	20.5	18.1	13.9	11.5	15.9	20.5	18.1	13.9	11.5
Domestic investment	21.6	18.7	17.9	35.1	32.5	19.1	20.6	23.3	42.6	31.6
Trade Balance	−8.2	3.2	6.7	12.5	−2.5	−5.8	1.4	1.4	5.5	−1.6
Net-export of										
low-tech good	−0.8	−1.6	−4.3	17.6	9.3					
high-tech good	−10.0	3.6	5.1	17.7	13.7					
investment good	2.6	1.2	5.9	−22.8	−25.5					
Current account	−3.1	5.3	3.1	−3.7	−26.8	−5.9	0.1	3.6	4.0	−3.0
Relative GDP levels	1.00	0.86	0.48	0.19	0.08	1.00	0.81	0.46	0.18	0.06
Government Indicators[a]										
Social benefits	14.1	20.6	16.3	4.0	3.4	14.3	20.7	16.5	4.0	
Social insurance revenues	9.0	16.5	14.7	4.0	3.4					
Payroll tax rate[b]	15.4	27.6	26.6	6.7	5.9	15.4		20.8	36.0	36.1
Tax revenues[a]	19.5	23.8	22.2	20.4	13.7	20.4	25.0	16.8	14.8	15.7
Direct taxes	11.7	11.3	10.7	5.0	2.5	12.9	11.6	8.3	2.8	5.4
Wage taxes	7.8	6.8	8.4	4.6	2.3					2.0
Capital taxes	3.9	4.5	2.3	0.3	0.3					3.4
Indirect taxes	7.8	12.5	11.5	15.4	11.1	7.5	13.4	8.5	12.0	10.3
Wage-tax rates[b]										
Average	13.4	11.3	13.9	7.8	4.0					
Marginal	14.5	12.2	14.7	7.9	4.0					
Consumption tax rate[b]	11.1	21.8	20.1	40.0	19.0					
Capital-output ratio	2.2	2.1	2.1	2.1	2.2					
Wealth-output ratio	3.0	2.8	2.5	1.0	0.75					

[a] In percent of GDP.
[b] In percent.

Table 5
Country-specific simulation results of the baseline path.

Year	GDP	Capital stock	Labor demand			Effective wage tax[a]	Payroll tax[a]	Average wage tax[a]	Consumption tax[a,b]
			Low	Middle	High				
U.S.									
2005	1.00	1.00	1.00	1.00	1.00	38.8	15.4	13.4	11.1
2030	1.68	1.58	1.75	1.69	1.81	55.8	23.8	17.8	16.6
2050	2.71	2.68	2.94	2.65	2.82	63.5	23.1	20.0	25.6
2100	4.57	4.00	5.38	4.76	5.01	69.9	28.5	20.7	26.1
EMU									
2005	0.86	0.83	0.76	0.83	0.96	56.8	27.6	11.3	21.8
2030	1.21	1.15	1.17	1.15	1.37	69.6	43.3	11.3	17.6
2050	1.75	1.76	1.85	1.64	1.85	73.2	42.4	12.3	22.7
2100	2.67	2.40	3.10	2.67	2.95	74.2	43.6	12.8	21.7
NEA									
2005	0.48	0.46	0.41	0.46	0.53	57.1	26.5	13.9	20.1
2030	0.72	0.66	0.73	0.73	0.80	68.2	35.5	14.9	21.7
2050	0.99	0.96	1.09	0.97	1.02	72.2	36.3	15.4	25.8
2100	1.27	1.13	1.57	1.34	1.36	70.3	35.8	16.6	21.8
China									
2005	0.19	0.19	0.20	0.18	0.21	43.1	6.7	7.8	40.0
2030	2.90	2.86	3.91	2.91	2.80	19.6	5.4	2.5	13.2
2050	5.03	5.59	8.20	4.90	4.06	21.0	11.7	2.2	7.6
2100	8.15	8.10	13.84	8.35	7.03	32.3	24.6	2.0	6.0
India									
2005	0.08	0.08	0.08	0.07	0.08	26.0	6.0	4.0	19.0
2030	1.26	1.23	1.47	1.24	1.30	24.3	4.2	3.4	20.1
2050	4.18	4.31	5.05	4.02	4.07	31.2	7.7	3.6	24.8
2100	11.76	11.04	17.81	12.19	11.32	43.3	19.7	4.4	23.8

The tax inclusive consumption tax rate (the nominal divided by 1 plus the nominal rate) is used in forming effective wage tax rates.
[a] In percent.
[b] These are nominal (tax exclusive) rates.

factors determining their time paths including inter-regional differences in saving behavior, demographics, and fiscal policies.

Consider next how average effective wage tax rates evolve. As indicated in Table 5, this tax rate comprises the payroll tax rate, the average wage (labor income) tax rate, and the average consumption tax rate.[17] All five regions experience dramatic increases over time in tax rates. In the U.S., average effective wage tax rates

[17] Consumption tax rates are expressed here on a tax inclusive basis to make it comparable to payroll and wage tax rates.

Table 6
GDP and its components in the baseline path.

	Year	Consumption/ GDP[a]	Investment/ GDP[a]	Gov. Purchases/ GDP[a]	Trade balance/ GDP[a]	Current account/ GDP[a]
U.S.	2005	70.7	21.6	15.9	−8.2	−3.1
	2030	62.9	20.2	20.3	−3.5	−5.9
	2050	45.0	20.7	21.2	13.1	−3.0
	2100	45.8	16.0	21.2	17.0	2.8
EMU	2005	57.6	18.7	20.5	3.2	5.3
	2030	68.8	19.2	24.2	−12.2	2.7
	2050	57.4	19.7	26.0	−3.1	0.7
	2100	61.8	16.3	25.9	−4.0	6.3
NEA	2005	57.3	17.9	18.1	6.7	3.1
	2030	55.2	18.7	22.5	3.6	0.8
	2050	48.2	19.1	24.6	8.1	1.3
	2100	59.2	15.8	24.1	0.8	5.9
China	2005	38.5	35.1	13.9	12.5	−3.7
	2030	55.0	27.1	14.1	3.8	13.0
	2050	81.1	24.1	16.1	−21.3	11.1
	2100	93.9	17.9	16.4	−28.2	0.0
India	2005	58.6	32.5	11.5	−2.5	−26.8
	2030	49.8	33.3	11.4	5.5	−25.0
	2050	44.3	26.5	12.6	16.6	−12.0
	2100	55.4	17.9	12.9	13.7	−3.2

[a] In percent.

rise from 38.8 percent in 2005 to 69.9 percent in 2100. This is a larger percentage increase than in the EMU, which starts with a 56.8 percent average rate and ends up in 2100 with an 74.2 percent average rate! In NEA, the average effective wage tax rate rises from 57.1 percent to 70.3 percent.

These are startlingly high tax rates in the case of the three developed regions. Do they make sense? They do given two factors. First, all three regions have very significant pay-go social insurance programs whose benefits are disproportionately distributed to the elderly. Given the dramatic aging (see Table 1) now underway, one would expect major tax hikes simply to finance these benefits. Second, healthcare benefit levels have risen and can be expected to continue to rise much faster than per capita GDP in each of the three regions. Recall that we are assuming for the U.S., EMU, and NEA a growth rate in healthcare benefit levels that is two percentage points higher than the growth rate of per capita GDP for the first 20 years of the transition and one percentage point higher for the following 10 years. As indicated in Hagist and Kotlikoff (2009), this is actually a rather conservative assumption. In the U.S., for example, the 1970-2002 average annual growth rate of real government healthcare benefit exceeded the average annual growth rate of per capita GDP by 2.6 percentage points. Since 2002, the differential appears to have been much larger thanks to the introduction of Medicare Part D prescription drug benefits and a huge expansion of Medicaid coverage.

Tax rates in both China and India also end up much higher at the end of the century, but before then they fall considerably, in the case of China, and moderately, in the case of India. The explanation is the expansion of the labor income of younger generations thanks to our assumptions concerning cohort-specific labor-productivity increases. Over time, as the entire labor force becomes fully productive and as these fully productive generations retire, their higher earnings histories translate into higher old age healthcare and pension benefits, whose financing requires higher tax rates. As indicated, we're also assuming a very sizable growth rate in healthcare benefit levels (4 percentage points above the growth rate of per capita GDP) for the next four decades in these two regions. Our rationale is that these countries are starting out with very low levels of healthcare benefits; and their governments will face strong pressure from their populations to improve this situation.

Table 5 shows the compositions of the tax rate increases. In the U.S. and EMU they are coming disproportionately from increases in payroll and consumption tax rates. In NEA, the major increase is from payroll taxes. This is also the case in India, where long-run average wage tax rates (the rates applied to wages via income taxation) differ either not at all or very little from their initial values and where long-run consumption tax rates are lower and, in the case of China, significantly lower, than their initial values. The decline in consumption tax rates compared to wage tax rates reflects the expansion of the consumption tax base relative to the wage tax base. The explanation lies in the significant aging of the two countries' populations, which generates relatively large numbers of elderly whose principal occupation is consuming. In China this is also due to the fact that initially the country runs a surplus that is fixed from 2019 onwards as a share of GDP at which point taxes become endogenous and fall reflecting, in part, the government's income on its ongoing stock of wealth.

Changes in factor prices are shown in Table 7. The interest rate increases during the next two decades and decreases afterwards. But it rises again during the second half of the century. In 2100 it ends up 120 basis points above the year-2005 value. These real interest rate developments are interesting; even more interesting is what happens to the levels and distribution of real wage rates.

According to Table 7, low-skilled wages per unit of effective time decrease continuously during the century. By mid-century the level of wages for low-skilled workers is only 71 percent of the year-2005 level; in 2100 it is only 65 percent of the initial level. Wages per unit of effective time for medium-skilled workers remain almost unchanged during the transition. In contrast, the wage rate of high-skilled workers per unit of effective time increases over the century; in 2050, it is 13.5 percent above its initial value. In 2100 it is 8.3 percent above the 2005 level. Wage-skill differentials in the medium and long runs are much larger than those that now exist. In 2005 the high-skilled wage rate exceeds the low-skilled rate by a factor of 5.9. By 2050 this factor is 9.5. In 2100 the factor is 9.9!

Producer prices remain remarkably constant during the transition. We see major changes in relative factor rewards with only minor changes in relative producer prices. Producer prices can be traced to unit costs, but when relative factor prices change, unit costs need change very little as the costs of some factors rise and others fall. In addition, substitution away from relatively expensive factors limits changes in producer prices.

Our model generates significant changes in the region-specific structure of production during the transition (see Table 10). Due to increasing government expenditures over time, the share of public good production in overall production rises over time in all five regions. Since high-skilled labor is relatively abundant in the developed regions, production in these regions is mainly concentrated in the skill-intensive sectors – namely high-tech and investment good production. In contrast, production in the low-tech traded good sector is essentially eliminated in the medium run in the developed regions. In the context of these results, which permit offshoring, "essentially eliminated" refers to producing, with the help of oversees labor, just enough (as in essentially zero) of the low-tech traded good to permit factor price equalization.

Table 7
Factor prices in the baseline path.

Year	Interest rate	Wage Rates[a]		
		Low	Middle	High
2005	11.6	1.00	2.97	5.92
2030	11.9	0.80	2.95	6.07
2050	10.5	0.71	3.01	6.72
2100	12.8	0.65	2.79	6.41

[a] At age 21 per unit of effective time.

In China and India, production of low-skill intensive goods (housing and the low-tech traded good) is significant, but the technological catch up process yields a very complex production pattern over time in these countries. During the transition, the developed regions are the major importers of the low-tech consumption good, while China and India are the world's primary exporter of this good. The high-tech good is mainly imported by the U.S. and China and exported by EMU, NEA and India. During the first two decades China and India are the main importers of the investment good while this good is exported by the developed regions. Afterwards EMU and China mainly import investment goods, while the U.S., NEA and India export these goods. Furthermore, all three developed regions become increasingly dependent over time on off-shore low-skilled labor. By mid-century about one fifth of the developed regions' low-skilled labor forces are hired off shore.

4.2. Transition path without offshoring

We now report baseline results assuming no offshore hires. Since many Chinese and Indian workers, particularly low-skilled workers, are no longer effectively employed abroad, turning off offshoring in our model means less output in the developed economies simply because they have fewer inputs to use to produce what gets counted as their output. And because China and India now have more inputs available to produce domestic output, their GDPs are higher. Furthermore, since the offshoring transition path featured more offshoring in the long than in the short run, there is an even larger impact on GDP levels over time. This translates, as shown in Table 8, into lower transitional growth rates in the developed regions and higher transition growth rates in China and India compared with those reported for the offshoring baseline.

Table 9 reports factor-price changes along the no-offshoring transition path. The first and quite interesting thing to note is that eliminating offshoring has no impact on the path of world interest rates. This implies that aggregate world capital formation is not impacted by offshoring. But without offshoring, wage rates of the low skilled are, as expected, higher in the developed regions and lower in the developing ones. As Table 10 indicates, this is especially true in NEA, where offshore hires, were they feasible, would be especially large in particular periods. Also note that the developed regions experience small increases in high-skilled wages. Hence, eliminating offshoring mitigates wage inequality in the developed economies, but worsens it in the developing economies. The table provides clear support for the contention of many developed country low-skilled workers that offshoring labor is significantly reducing their wages.

Table 8
Baseline path without offshoring.

	Year	GDP[a]	Capital stock[a]	Labor demand[a]		
				Low	Middle	High
U.S.	2005	0.0	0.0	0.0	0.0	0.0
	2030	−2.8	−2.1	−9.0	−3.6	−2.0
	2050	−6.0	−4.2	−21.5	−8.1	−4.4
EMU	2005	0.0	0.0	−0.1	0.0	−0.1
	2030	−3.2	−2.3	−11.4	−4.4	−2.3
	2050	−6.1	−4.1	−22.6	−8.2	−4.7
NEA	2005	−0.1	−0.1	−0.2	0.0	−0.1
	2030	−4.4	−3.3	−15.7	−5.7	−3.3
	2050	−6.2	−4.3	−23.1	−7.8	−4.9
China	2005	0.0	0.1	0.0	0.0	0.0
	2030	2.5	1.5	8.2	3.6	2.0
	2050	2.8	1.8	10.0	3.8	2.3
India	2005	0.0	0.1	0.0	0.0	0.0
	2030	2.6	1.5	8.0	3.9	2.4
	2050	4.0	2.8	11.5	5.6	3.4

[a] Changes to respective baseline values in percent.

Table 9
Factor prices without offshoring.

	Year	Interest rate[a]	Wage rates[a,b]		
			Low	Middle	High
U.S.	2005	0.0	0.1	0.0	0.0
	2030	0.0	5.3	−0.7	0.0
	2050	0.0	14.8	−1.6	0.2
EMU	2005		0.1	0.0	0.0
	2030		7.2	−0.9	0.0
	2050		16.7	−1.8	0.3
NEA	2005		0.1	0.0	0.0
	2030		10.5	−1.3	0.1
	2050		17.7	−1.9	0.3
China	2005		0.1	0.0	0.0
	2030		−4.5	0.5	−0.3
	2050		−5.6	0.8	−0.4
India	2005		0.1	0.0	0.0
	2030		−4.5	0.5	−0.3
	2050		−5.6	0.8	−0.4

[a] Changes to respective baseline values in percent.
[b] at age 21 per unit of effective time

The reported changes over time in factor prices can best be understood by considering the changes in the demands for output by the private sector, the government, and the international market. Interestingly, the structure of domestic demand changes relatively little over time. This is surprising given the aging of regional populations and the fact that preferences are age-specific (see Table 2). These factors suggest an increasing demand for services and a declining demand for high-tech goods. But these factors aren't sufficiently strong, in light of other factors at play during the transition, to materially alter relative aggregate demands for consumer goods and services.

However, the changing population structure increases government demand for public goods and the rising international supply of saving raises demand for investment goods produced in developed economies. Table 10 compares the region-specific structure of production during the transition with and without offshoring. Without offshoring the developed regions shift their traded goods production from the investment good sector to the high-tech consumer good sector. The explanation is the fact that high-tech good production is much more high-skilled-labor intensive than is investment good production and the developed countries now find low-skilled workers relatively expensive and high-skilled workers relatively cheap. These changes in the production structure in the industrialized countries prevent high-skilled wages from falling as much as one might have expected and as can be observed for the middle-skill class. Of course, opposite forces come into play for China and India.

The changes in trade patterns displayed in Table 11 are also worth mentioning. Absent offshoring, China and India become, as one would expect, bigger players in international trade. China, for example, becomes the largest producer of the low-tech good by mid-century. This is not surprising since the catchup in productivity in China occurs much faster than in India, and thus production in China is much more focused on the low-skilled-intensive, low-tech good sector.

Finally, Table 12 shows the welfare effects of eliminating offshoring measured as Hicksian equivalent variation and expressed as a percentage of remaining lifetime resources. Older cohorts experience negligible changes in their welfare since they are little affected by the new paths for factor prices and tax rates. In contrast, today's and tomorrow's low-skilled cohorts in the developed regions experience sizeable welfare gains. Consider, for example, a U.S. low-skilled worker who will be born in 2030; this worker experiences a welfare gain of 10.7 percent if production is not offshored. The welfare gains are much smaller for middle- and

Table 10
Production and trade balance with and without offshoring.

	Share of good in domestic production[a]						Trade balance[b] for			Offshore labor[c]		
	Services	Housing	Low tech	High tech	Invest. Good	Public Good	Low tech	High tech	Invest. Good	Low	Middle	High
U.S.	*Transition path with offshoring*											
2005	5.7	29.5	10.6	14.1	24.2	15.9	−0.8	−10.0	2.6	0.0	0.0	0.0
2030	5.9	26.3	0.0	17.4	30.1	20.3	−10.0	−3.3	9.8	−9.2	−3.5	−1.8
2050	4.1	18.9	0.0	23.9	31.8	21.2	−7.2	9.1	11.1	−21.3	−8.0	−3.8
EMU												
2005	4.8	24.1	7.7	23.1	19.9	20.5	−1.6	3.6	1.2	0.0	0.0	0.0
2030	6.9	28.8	0.0	25.6	14.5	24.2	−10.8	3.3	−4.7	−11.7	−4.4	−1.8
2050	6.0	24.1	0.0	25.8	18.2	26.0	−9.0	7.5	−1.5	−22.5	−8.1	−3.4
NEA												
2005	5.1	23.9	4.9	24.3	23.8	18.1	−4.2	5.1	5.9	0.0	0.0	0.0
2030	5.6	23.2	0.0	17.5	31.3	22.5	−8.7	−0.2	12.5	−15.5	−5.6	−2.8
2050	4.8	20.2	0.0	18.8	31.5	24.6	−7.6	3.3	12.4	−21.8	−7.3	−3.4
China												
2005	2.5	16.1	23.9	31.3	12.3	13.8	17.6	17.7	−22.8	0.0	0.0	0.0
2030	3.0	23.2	20.3	16.6	22.8	14.1	11.2	−3.1	−4.3	7.7	3.6	1.9
2050	5.4	33.9	22.3	9.8	12.5	16.1	9.1	−18.8	−11.6	8.9	3.9	2.0
India												
2005	3.6	24.5	18.9	34.6	6.9	11.5	9.3	13.7	−25.5	0.0	0.0	0.0
2030	2.5	20.9	11.1	26.7	27.5	11.4	2.8	8.5	−5.9	7.6	3.8	2.2
2050	2.5	18.6	6.6	28.8	31.0	12.6	−0.7	12.8	4.5	10.8	5.6	3.1
U.S.	*Transition path without offshoring*[d]											
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2030	0.2	0.9	0.0	2.7	−3.8	0.0	−0.3	2.0	−3.6			
2050	0.4	1.5	0.0	6.9	−8.6	0.0	−0.5	5.7	−8.9			
EMU												
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2030	0.3	1.1	0.0	3.5	−5.0	0.0	−0.5	2.7	−4.9			
2050	0.4	1.9	0.0	6.7	−9.2	0.0	−0.7	5.2	−9.4			
NEA												
2005	0.0	0.0	−0.1	−0.1	0.1	0.0	−0.1	−0.1	0.1			
2030	0.3	1.3	0.0	4.7	−6.5	0.0	−0.5	3.7	−6.5			
2050	0.4	1.8	0.0	6.3	−8.4	−0.1	−0.7	4.9	−8.7			
China												
2005	0.0	0.0	0.1	0.0	−0.1	0.0	0.1	0.1	−0.1			
2030	−0.1	−0.7	−0.3	−2.6	3.7	0.0	0.0	−2.1	3.9			
2050	−0.2	−1.1	−0.1	−3.0	4.3	0.0	0.3	−2.1	4.5			
India												
2005	0.0	0.0	0.0	0.0	−0.1	0.0	0.1	0.1	−0.2			
2030	−0.1	−0.7	−0.7	−2.8	4.2	0.0	−0.4	−2.2	4.5			
2050	−0.2	−0.9	−0.8	−4.0	5.8	0.0	−0.5	−3.2	6.0			

[a] in percent.
[b] in percent of GDP.
[c] in percent of domestic skill-specific labor demand.
[d] changes to respective baseline values in percentage points

Table 11
Output shares in production with and without offshoring.

	Year	With offshoring			Without offshoring[a]		
		Low tech	High tech	Investment good	Low tech	High tech	Investment good
U.S.	2005	41.2	25.9	43.5	0.1	0.0	0.0
	2030	0.0	18.9	26.4	0.0	2.4	−3.9
	2050	0.0	21.8	25.3	0.0	4.5	−8.0
EMU	2005	25.7	36.5	30.8	0.0	0.0	0.0
	2030	0.0	20.0	9.1	0.0	2.0	−3.2
	2050	0.0	15.1	9.3	0.0	2.8	−5.0
NEA	2005	9.0	21.2	20.4	−0.1	0.0	0.0
	2030	0.0	8.1	11.8	0.0	1.8	−2.8
	2050	0.0	6.2	9.1	0.0	1.6	−2.9
China	2005	18.1	11.2	4.3	0.0	0.0	0.0
	2030	80.8	31.2	34.5	0.8	−4.4	6.7
	2050	80.4	16.5	18.4	1.7	−4.7	6.9
India	2005	5.9	5.1	1.0	0.0	0.0	0.0
	2030	19.2	21.7	18.1	−0.8	−1.7	3.4
	2050	19.6	40.3	37.9	−1.7	−1.8	8.9

[a] Changes to respective baseline values in percentage points.

Table 12
Welfare effects of offshoring[a].

Birth year	U.S. Income class 1	U.S. 2	U.S. 3	EMU Income class 1	EMU 2	EMU 3	NEA Japan Income class 1	NEA Japan 2	NEA Japan 3
1940	0.00	0.01	0.01	0.00	0.01	0.02	−0.05	0.04	0.04
1980	0.44	0.01	0.05	0.62	0.08	0.14	1.60	0.13	0.28
2000	4.09	0.29	0.55	5.22	0.68	0.78	8.83	1.06	1.06
2010	7.76	0.77	1.22	8.33	1.18	1.40	12.00	1.44	1.53
2020	10.05	1.04	1.60	10.20	1.42	1.92	13.81	1.60	1.86
2030	10.75	1.10	1.70	10.79	1.42	2.10	14.26	1.57	1.99

Birth year	China Income class 1	China 2	China 3	India Income class 1	India 2	India 3
1940	0.07	−0.03	−0.02	0.10	0.01	0.03
1980	−0.68	−0.05	−0.15	−0.61	0.00	−0.11
2000	−2.97	0.00	−0.21	−3.88	−0.07	−0.52
2010	−3.67	0.07	−0.28	−4.75	−0.18	−0.69
2020	−3.77	0.15	−0.26	−4.99	−0.25	−0.74
2030	−3.63	0.25	−0.20	−4.88	−0.31	−0.76

[a] HEV in percent of (remaining) lifetime resources.

Table 13
Simulation results of the transition path without China and India.

	Year	GDP[a]	Capital stock[a]	Labor demand[a]			Consumption/GDP[b]	Investment/GDP[b]	Gov. Purchases/GDP[b]	Trade Balance/GDP[b]	Payroll tax rate[b]	Average wage tax[b]	Consumption tax[b]
				Low	Middle	High							
U.S.	2005	2.4	7.9	−2.4	−0.8	0.0	−1.0	0.8	−0.3	0.5	−0.1	−0.2	−0.1
	2030	1.6	5.3	−8.9	−0.9	1.7	−2.9	−2.2	−0.6	5.8	−0.4	−0.4	0.7
	2050	−14.5	−20.9	−25.1	−11.3	−6.7	9.8	−3.3	−1.2	−5.3	1.5	−1.6	−5.4
	2100	−7.6	−5.0	−25.6	−10.2	−2.5	6.7	0.4	−1.1	−6.1	−0.5	−1.9	−4.5
EMU	2005	3.0	8.6	−1.4	−0.2	0.4	−1.3	0.4	−0.5	1.4	−0.4	−0.2	0.1
	2030	0.3	3.5	−11.0	−1.7	0.7	−2.5	−2.2	−0.8	5.5	−2.0	0.0	1.1
	2050	−15.3	−21.1	−26.5	−13.2	−7.5	13.7	−3.0	−1.4	−9.2	0.3	−0.9	−5.2
	2100	−8.9	−5.9	−28.3	−12.2	−3.7	11.4	0.6	−1.3	−10.7	−2.5	−1.4	−4.7
NEA	2005	2.6	7.9	−1.4	−0.6	−0.2	−1.0	0.3	−0.4	1.1	−0.2	−0.4	−0.2
	2030	−2.3	0.9	−16.3	−4.7	−1.3	0.1	−1.8	−0.7	2.4	−1.8	−0.6	−0.1
	2050	−15.6	−21.7	−26.6	−12.2	−8.2	12.2	−2.9	−1.3	−8.0	−0.7	−0.3	−5.0
	2100	−8.5	−5.8	−30.1	−11.9	−2.4	10.4	0.5	−1.1	−9.8	−1.8	−1.6	−4.0

Changes to the respective baseline values in
[a] percent or.
[b] percentage points.

high-skilled workers. The explanation is straightforward. While wage rates for medium-skilled workers decline compared to the case of offshoring, there are opposite effects from reduced tax rates, which dominate the wage reduction and lead to small welfare gains. High-skilled workers primarily benefit from slightly higher wages and reduced wage tax and consumption tax rates. The differences in welfare gains in the U.S., EMU and NEA are a direct consequence of the different regional effects on wage and tax rates.

In China and India, however, workers experience welfare losses if offshoring is shut down.

4.3. Alternative policies

This section considers alternative policies assuming, what seems most empirically defensible, that offshoring is feasible. We explore first how shutting down trade with China and India would affect the developed regions. We consider this case by simply excluding India and China from our simulation model. The calibration of the remaining regions remains unchanged. Table 13 reports macroeconomic variables. Note that we express all values as changes in percent or percentage points to their respective baseline values.

As the table indicates, excluding China and India has dramatic effects on the economic development in the developed regions. Capital stocks in all three regions in the initial year of the transition are higher compared to the five-region case since more capital now remains in the developed world. For example, in 2005 the capital stock in the U.S. is 7.9 percent higher than in the five-region simulation (see Table 5). However, in all three regions, capital stocks as well as levels of GDP grow to a much smaller extent over time compared with the baseline. Payroll tax rates, however, increase to a smaller extent over the whole transition path.

The most interesting finding of excluding China and India is its impact on the wage structure, see Table 14. As before, wage rates for low-skilled workers decrease during the transition but to a much smaller extent than in the baseline. By the end of the century, the low-skilled wage rate is 92 percent of the year-2005 level; this means an increase by 51.9 percent compared to the year-2100 level in the base case. The reason, of course, is that absent China and India there is no major increase over time in the relative world supply of low-skilled workers. Wages for middle-skilled workers are largely unchanged, but the high-skilled wage rate ends up 7.6 percent below its 2005 level compared to 8.3 percent above its 2005 level when China and India are included. This is a reduction of 12.4 percent compared to the year-2100 baseline value.

Developed world long-run GDPs are also significantly affected by moving to autarky with respect to China and India. For example, U.S. GDP in 2100 is reduced by 7.6 percent. Total developed region GDP is reduced by 8 percent. These reductions in GDP suggest that there are sizeable gains from trade, which could be shared with low-skilled workers were the developed countries to adopt the right redistribution policies. Exploring such policies is on our agenda for the next draft of this paper.

To assess the sensitivity of our results to our labor productivity assumptions, we ran two further simulations. The first assumes that the labor productivity of successive new cohorts of workers in China increases to the developed world's level in 25 years instead of 15 years. The second run assumes an adjustment over 50 years. Since the qualitative results of these two simulation runs were very similar, with much slower economic growth in China in the short and medium runs than in the baseline path, we just report the outcomes of adjusting individual productivity in China within 50 years. For example, China's 2030 GDP is now only 50 percent of its baseline level. Slower growth in China means a smaller supply of Chinese saving to the rest of the world. This, in turn, means lower rates of domestic investment and slower rates of growth in the other four regions. This translates into higher payroll and other tax rates and less growth in real wage rates, particularly among middle- and high-skilled workers (see Table 14).

Finally, we simulated successful education policy in China and India by which we mean that over the next 30 years the two countries succeed in providing new cohorts with the same distribution

Table 14
Factor prices in alternative policy paths.

	Year	Interest rate[a]	Wage rates[a,b]		
			Low	Middle	High
Eliminating Trade with China and India	2005	−0.9	5.7	2.4	2.6
	2030	−0.3	28.1	1.4	−3.7
	2050	2.2	37.1	−3.9	−14.9
	2100	0.1	51.9	3.8	−12.4
Different Labor Productivity in China	2005	0.0	0.4	0.0	0.1
	2030	1.1	7.5	−2.3	−5.4
	2050	2.7	3.4	−6.4	−10.0
	2100	−0.4	1.1	1.0	1.3
Adjusting Income Class Shares	2005	0.0	0.0	0.1	−0.2
	2030	0.1	14.0	0.7	−3.8
	2050	0.0	32.5	2.0	−7.6
	2100	0.0	54.9	3.9	−12.3

[a] Changes to respective baseline values in percent.
[b] at age 21 per unit of effective time

Table 15
Successful Chinese and Indian education policy[a].

Year	GDP	Capital stock	Labor demand			Effective wage tax	Payroll tax	Average wage tax	Consumption tax
			Low	Middle	High				
U.S.									
2005	0.0	0.0	−0.5	0.0	0.3	0.0	0.0	0.0	0.0
2030	−3.2	−2.6	−9.5	−3.8	−2.1	−1.1	−0.1	−0.5	−0.7
2050	−7.2	−5.9	−22.6	−8.4	−3.4	−3.6	−0.3	−1.5	−2.7
2100	−5.9	−3.1	−25.4	−9.2	0.0	−3.0	0.1	−1.4	−2.6
EMU									
2005	−0.1	−0.1	−0.4	0.0	0.1	−0.1	0.0	0.0	−0.1
2030	−3.8	−3.4	−11.7	−4.5	−2.1	−2.1	−1.0	−0.4	−0.9
2050	−7.4	−6.1	−23.5	−8.7	−3.5	−4.4	−2.0	−0.8	−2.3
2100	−6.9	−4.0	−28.0	−10.8	−0.2	−4.3	−1.9	−0.8	−2.3
NEA									
2005	0.0	−0.2	−0.5	0.0	0.1	0.0	0.0	0.0	0.0
2030	−4.5	−4.6	−14.3	−4.3	−2.6	−2.1	−1.1	−0.4	−0.9
2050	−7.5	−6.2	−23.8	−8.6	−3.5	−4.8	−2.0	−1.0	−2.8
2100	−7.3	−4.5	−30.2	−11.6	−0.3	−4.6	−1.7	−1.2	−2.5
China									
2005	0.0	0.0	−0.5	0.0	0.3	0.0	0.0	0.0	0.0
2030	6.0	4.9	−10.1	5.1	12.3	0.5	0.0	0.1	0.6
2050	9.6	8.6	−20.9	6.8	22.6	0.2	−0.1	0.0	0.4
2100	8.9	7.8	−35.2	4.3	29.3	−0.2	−0.1	0.0	−0.1
India									
2005	0.0	0.0	−0.5	0.0	0.3	0.0	0.0	0.0	0.0
2030	6.6	5.3	−11.1	5.5	13.1	0.2	0.0	0.0	0.3
2050	10.7	9.4	−20.6	8.6	22.0	0.6	0.0	0.1	0.9
2100	11.1	9.8	−31.9	7.2	29.3	0.5	−0.1	0.1	0.8

[a] Changes to respective baseline values in percentage points

of skills as is the case for new cohorts in the developed economies.[18] Recall that in 2005, we assume that 22 percent of the overall population in China and India belong to the low-skill group, 25 percent to the highest, and 53 percent to the middle. By 2035, these shares have converged to 15, 55, and 30 percent, respectively.

Simulating this policy generates little difference in overall macroeconomic conditions (see Table 15). The main effect is on relative GDPs. Year-2100 GDPs in the developed regions are about 6 percent smaller, while they are about 10 percent larger in China and India. The real impact of the policy is on wages. As shown in Table 14, the wage rates per efficiency unit of all three skill classes now ultimately increase and wage inequality remains roughly constant over time. Rather than falling to .65 in 2100, the low-skilled wage is now 1.00 at Century's end. This is an increase by 54.9 percent compared to the respective baseline value. This improvement in low-skilled wage rates comes at the price of a wage-rate reduction for high-skilled workers. In 2100 their wage rate declines by 12.3 percent compared to the base case. As for inequality, the base-case ratio of high-skilled to low-skilled wage rates in 2100 was 9.9. It's now 5.6. The middle-skilled workers also experience some improvement in their relative remuneration. Their long-run wage rate rises by 3.9 percent compared to the base case.

5. Conclusions

This paper developed a new 5-region, dynamic, general equilibrium, life-cycle model to analyze the impact of globalization on the world's demographic/fiscal transition path, particularly the course of wage inequality. Our model includes multiple traded and non-traded goods whose production functions differentially utilize high-skilled, middle-skilled, and low-skilled labor as well as capital. Thanks to the projected catch-up of labor productivity in China and India and the fact that these regions are relatively highly endowed with low-skilled workers, there is an ongoing and very major increase in the world's relative endowment of low-skilled labor. This portends further dramatic increases in wage rate inequality over the century.

If developed regions are free to hire labor, albeit remotely, from China and India, in what we term offshoring, world-wide factor-price equalization and incomplete specialization is assured. But if such offshoring is precluded, specialization will arise. In this case, the general trend toward increasing wage inequality still materializes, but inequality is mitigated in the developed regions, which would otherwise be remotely hiring primarily low-skilled workers from China and India. On the other hand, wage inequality in China and India is exacerbated.

Our model also shows that the dramatic aging process now underway in the developed world, China and, ultimately, India, coupled with very high projected growth rates in government-financed healthcare benefits, will greatly challenge fiscal institutions leading to tremendous increases in effective wage-tax rates – increases that are barely feasible in our model and may be infeasible in the real world. Notwithstanding these tax hikes, the model predicts world-wide capital deepening thanks to large supplies of capital forthcoming from China and India, whose saving rates are assumed to remain relatively high for many years to come.

Excluding China and India from trade with the developed regions succeeds in limiting wage-rate inequality. But it comes at a major cost to developed world output, reducing the long-run (year 2100) GDP of the U.S., EMU, and Japan (plus Taiwan and Korea) by 8 percent compared with the case of free trade. It also reduces capital intensivity, raising real interest rate by 220 basis point in 2050. On the other hand, this policy keeps the wage rates of low-skilled workers from falling over time, leaves the long-run wage rate of middle-skilled workers essentially unchanged, and leaves the long-run wage rates of high skilled workers 8 percent lower rather than 8 percent higher.[19]

[18] Note that we still assume that members of each income class inherit from their parents' skill class.

[19] These wage rates are measured per efficiency unit and abstract from the model's assumed increase in the labor efficiency of successive cohorts no matter their skill levels. This efficiency increase, recall, comes in the form of expansion in effective time endowments.

In suggesting that trade with China and India may increasingly undermine the relative prospects of low-skilled and middle-skilled workers, we don't contend that this troubling aspect of globalization has been the dominant force in recent decades in exacerbating income inequality. But the main future concern is surely the effective arrival of hundreds of millions of low-skilled Chinese and Indian workers able to compete on equal terms with low-skilled workers in the developed world.

Worsening wage rate inequality is not inevitable, however. As we show, if Chinese and Indian education policies begin to produce new high-, middle-, and low-skilled workers in the same proportions as now occurs in the developed regions, the exacerbation of wage inequality can be fully reversed. Consequently, one of the best ways the developed world can assist its unskilled workers is to help improve education in China and India.

Acknowledgements

Research support by the Fritz Thyssen Stiftung and Netspar is gratefully acknowledged. We thank Robert Lawrence for helpful comments.

References

Altig, D., Auerbach, A.J., Kotlikoff, L.J., Smetters, K.A., Walliser, J., 2001. Simulating fundamental tax reform in the United States. American Economic Review 91, 574–595.
Auerbach, A.J., Kotlikoff, L.J., 1987. Dynamic Fiscal Policy. Cambridge University Press, Cambridge.
Autor, D.H., Katz, L.F., Kearney, M.S., 2008. Trends in U.S. wage inequality: reassessing the revisionists. Review of Economics and Statistics 90, 300–323.
Autor, D.H., Katz, L.F., Kearney, M.S., 2006. The polarization of the U.S. labor market. American Economic Review 96, 189–194.
Barro, R.L., Lee, J.W., 2001. International data on educational attainment: updates and implications. Oxford Economic Papers 53, 541–563.
Bloom, D.E., Canning, D., Hu, L., Liu, Y., Mahal, A., Yip, W., 2010. The contribution of population health and demographic change to economic growth in China and India. Journal of Comparative Economics 38, 17–33.
Bosworth, B., Collins, S.M., 2008. Accounting for growth: comparing China and India. Journal of Economic Perspectives 22, 45–66.
Bound, J., Johnson, G., 1992. Changes in the structure of wages in the 1980's: an evaluation of alternative explanations. American Economic Review 82, 371–392.
Braun, R.A., Ikeda, D., Joines, D.H., 2009. The saving rate in japan: why it has fallen and why it will remain low. International Economic Review 50, 291–321.
Card, D., DiNardo, J.E., 2002. Skill-biased technological change and rising wage inequality: some problems and puzzles. Journal of Labor Economics 20, 733–783.
Council for Economic Planning and Development (CEPD), 2007. Population Projections for Taiwan Area 2006-2051. <http://www.cepd.gov.tw/>.
Deutsche Bank Research, 2006. China's pension system. Current Issues, China Special, February 17, 2006, Frankfurt.
Domeij, D., Flodén, M., 2006. Population aging and international capital flows. International Economic Review 47, 1013–1032.
Eckstein, Z., Nagypal, E., 2004. The evolution of U.S. earnings inequality 1961– 2002. Federal Reserve Bank of Minneapolis Quarterly Review 28, 10–29.
European Commission, 2008. Statistical Annex of European Economy. Spring 2008, Brussels.
European Commission, 2007. Economic Forecast Spring 2007. European Economy 2, Brussels.
Feenstra, R.C., Hanson, G.H., 1999. The impact of outsourcing and high-technology capital on wages: estimates for the United States, 1979–1990. Quarterly Journal of Economics 114, 907–940.
Feenstra, R.C., Hanson, G.H., 1996. Globalization, outsourcing and wage inequality. American Economic Review 86, 240–245.
Fehr, H., Jokisch, S., Kallweit, M., Kindermann, F., Kotlikoff, L.J., 2013. Generational policy and aging in closed and open dynamic general equilibrium models. In: Dixon, P.B., Jorgensen, D.W. (Eds.), Handbook of Computable General Equilibrium Modeling. Elsevier, pp. 1719–1800.
Fehr, H., Jokisch, S., Kotlikoff, L.J., 2008. Dynamic Globalization and Its Potentially Alarming Prospects for Low-Wage Workers. NBER Working Paper No. 14527, Cambridge.
Fehr, H., Jokisch, S., Kotlikoff, L.J., 2007. Will China eat our lunch or take us to dinner? simulating the transition paths of the United States, the European Union, Japan, and China. In: Ito, T., Rose, A.K. (Eds.), Fiscal Policy and Management in East Asia. University of Chicago Press, pp. 133–193.
Fehr, H., Jokisch, S., Kotlikoff, L.J., 2005. The developed world's demographic transition – the roles of capital flows, immigration and policy. In: Brooks, R., Razin, A. (Eds.), Social Security Reform – Financial and Political Issues in International Perspective. Cambridge University Press, pp. 11–43.
Gordon, R.J., Dew-Becker, I., 2007. Selected issues in the rise of income inequality. Brookings Papers on Economic Activity 38, 169–192.
Hagist, C., Kotlikoff, L.J., 2009. Who's Going Broke? Comparing Healthcare Costs in ten OECD Countries. Hacienda Pública Española 188, 55–72.
Heckman, J.J., Lochner, L., Taber, C., 1998. Explaining rising wage inequality: Explorations with a dynamic general equilibrium model of labor earnings and heterogeneous agents. Review of Economic Dynamics 1, 1–58.
Hornstein, A., Krusell, P., Violante, G.L., 2005. The effects of technical change on labor market inequalities. In: Aghion, P., Durlauf, S.N. (Eds.), Handbook of Economic Growth 1B. Elsevier, Amsterdam, pp. 1275–1370.
Kennickell, A.B., Starr-McCluer, M., Surette, B.J., 2000. Recent changes in U.S. family finances: results from the 1998 survey of consumer finances. Federal Reserve Bulletin 86, 1–29.
Kotlikoff, L.J., Smetters, K.A., Walliser, J., 2007. Mitigating America's demographic dilemma by pre-funding social security. Journal of Monetary Economics 54, 247–266.
Lawrence, R.Z., 2008. Blue-Collar Blues: Is Trade to Blame for Rising U.S. Income Inequality?, Washington D.C.
Lemieux, T., 2006. Increasing residual wage inequality: composition effects, noisy data, or rising demand for skill? American Economic Review 96, 461–498.
OECD, 2008. Employment Outlook, Paris.
OECD, 2007a. OECD Health Data 2007: Statistics and Indicators for 30 Countries, Paris.
OECD, 2007b. Pensions at a Glance, Public Policies Across OECD Countries, Paris.
OECD, 2007c. Social Expenditure Database (SOCX 2007), 1980–2003, Paris.
OECD, 2007d. Main Economic Indicators, December, Paris.
OECD, 2006. Education at a Glance, OECD Indicators 2006, Paris.
OECD, 2005. China, Economic Surveys, Vol. 2005/13, Paris.
OECD, 2002. China in the World Economy: The Domestic Policy Challenges, Paris.
Piketty, T., Saez, E., 2003. Income inequality in the United States, 1913–1998. Quarterly Journal of Economics 118, 1–39.
Poirson, H., 2006. The Tax System in India. IMF Working Paper 06/93, Washington.
Sachs, J.D., Shatz, H.J., 1996. U.S. trade with developing countries and wage inequality. American Economic Review 86, 234–239.
Social Security Association (SSA), 2007. Social Security Programs Throughout the World: Asia and the Pacific, 2006, Washington D.C.
Social Security Association (SSA), 2006. Social Security Programs Throughout the World: The Americas, 2005, Washington D.C.
Statistics Bureau Japan, 2002. 1999 National Survey of Family Income and Expenditure, Vol. 7: Reference Material, No. 2: Family Assets, Tokyo.
Timmer, M., van Moergastel, T., Stuivenwold, E., Ypma, G., O'Mahony, M., Kangasniemi, M., 2007. EU Klems Growth and Productivity Accounts, Groningen Growth and Development Centre and NIESR London. <http://www.euklems.net/>.
United Nations Population Division (UNPD), 2007. World Population Prospects: The 2006 Revision, New York.
U.S. Census Bureau, 2008. Current Population Survey, 2007 Annual Social and Economic Supplement, Washington D.C.
U.S. Department of Labor, 2007. Consumer Expenditures in 2005. U.S. Bureau of Labor Statistics Report 998, Washington.
Wang, Y., Xu, D., Wang, Z., Zhai, F., 2004. Options and impact of China's pension reform: a computable general equilibrium analysis. Journal of Comparative Economics 32, 105–127.
Wang, Z., Schuh, E.G., 2002. The emergence of a greater China and its impact on world trade: a computable general equilibrium analysis. Journal of Comparative Economics 30, 531–566.
Wei, Z., Hao, R., 2010. Demographic structure and economic growth: evidence from China. Journal of Comparative Economics 38, 472–491.
World Bank, 2007. World Development Indicators Database, Washington.
World Bank, 2005. South Asia Pension Schemes for the Formal Sector, Finance and Private Sector Development Unit, Washington.
Wood, A., 1998. Globalization and the rise in labour market inequalities. Economic Journal 108, 1463–1482.
Valentinyi, A., Herrendorf, B., 2008. Measuring factor income shares at the sectoral level. Review of Economic Dynamics 11, 820–835.
Zhu, S.C., Trefler, D., 2005. Trade and inequality in developing countries: a general equilibrium analysis. Journal of International Economics 65, 21–48.