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Global Growth, Aging and Inequality Across and Within Generations

Discussion Paper 03/2010-045

Global growth, aging and inequality across and within generations

Hans Fehr,* Sabine Jokisch,** and Laurence J. Kotlikoff***

Abstract

The world's leading economies, both developed and developing, are engaged in an ever changing economic symbiosis that is governed in large part by demographics and technological change, but also by pension, healthcare, and other fiscal policies. This interconnected economic evolution – what economists call general equilibrium growth -- holds important implications for inequality across and within generations. This paper presents such a general equilibrium model. It features six goods, five regions, three skill groups, and 100 overlapping generations each making life-cycle consumption and labor supply decisions. The model pays special attention to the evolution of the Chinese and Indian economies. Thanks to their rapid technological advance and vast populations, these nations will play an ever more dominant role in determining the world's supplies of capital and labor, particularly unskilled labor. The good news for the developed world is that China and India will supply it with major amounts of capital over time thanks to their high saving rates. The bad news is that these economies are also likely to bring much more unskilled relative to skilled labor onto the market which will, over time, dramatically reduce the relative wages of unskilled workers in the U.S., Europe, and Japan. This relative increase in the world supply of unskilled workers reflects, in large part, simply the fact that China and India are gradually bringing each of their skill groups up to Western standards, but that they have relatively more unskilled labor in their work forces.

Key words: Demographic transition, overlapping generations (OLG), computable general equilibrium models (CGE), international trade, wage inequality, economic growth
JEL classification: F0, F20, H0, H3, J20, O0, O23

I. INTRODUCTION

The global economy is changing dramatically before our eyes. China and, to a lesser extent, India are on a path to not just match the developed world in terms of per capita output, but to become, for all intents and purposes, the developed world given their vast population sizes. Indeed, if China's per capita GDP continues to grow at its torrid pace, the relationship of the U.S. economy to the Chinese economy will, by mid century, resemble the relationship between Canada and the U.S. today.

Thus how China, India, and other developing countries in East Asia evolve in conjunction with the U.S., Japan, and Europe is the growth question of our times and one that matters for all major economic issues, including inequality across and within generations. It's also a very tough question to consider because there are some many moving and interconnected parts. These include the aging of China and India as well as the developed regions, lifespan extension, the pace of technological change in China and India and other East Asian economies, the evolution of healthcare spending, Social Security benefits, and discretionary government spending and the degree to which these government payments are left for future generations to cover.

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At the moment, East Asian populations are relatively young compared to those of industrialized countries. But they too also face major demographic changes in the coming decades. Indeed, by mid Century, China will be older than the U.S.; i.e., it's share of the population over 65 will exceed that in the U.S. Furthermore, China and India are endowed with a large number of low-skilled workers. Future productivity improvements are therefore expected to increase the worldwide relative supply of unskilled labor. This relative increase in the world supply of unskilled workers reflects, in large part, simply the fact that China and India are gradually bringing each of their skill groups up to Western standards, but that they have relatively more unskilled labor in their work forces to begin with.

This increase in the relative abundance of low-skilled workers will, of course, have a major impact on the worldwide wage structure and cause distributional effects across and within generations. This is simply a matter of supply and demand. Other things equal, a larger supply of unskilled workers will depress the wages of the unskilled. Given the economic relevance of Asian countries in an ever more globalized world, including these regions in modeling the developed world is essential. So too is incorporating immigration to and emigration from these regions.

Examining these interconnected economic factors and policies requires the use of computable general equilibrium (CGE) models. The formal mathematical structure of these models entails the assumption that all markets for goods and factor inputs (labor and capital) clear; i.e., that supplies equal demands not just in the present, but at all future dates.

Most such models focus on the economic effects of population aging in industrialized countries in closed-economy frameworks (models in which the economies in question have no other countries with whom to trade). But there are also several multi-region models that incorporate international capital flows and global competition. Yet they pay little, if any, attention to how China, India, and other developing countries in eastern Asia will influence economic developments in Japan and the West.

This paper presents a new dynamic, life-cycle, CGE model with overlapping generations (OLG) to study the interdependent demographic, fiscal, and economic transition paths of the U.S., the European Monetary Union (EMU), Northeast Asia (NEA) − consisting of Japan, Korea, Taiwan, and Hong Kong −, China, and India. In each region we calibrate population dynamics to those projected by the United Nations Population Division. Thus our model captures the rapid and significant aging processes in the developed world and China that will require major fiscal adjustments as well as the more moderate demographic developments in India.

Within each cohort there are three skill and, thus, income classes. Consequently, the model is able to take into account differences in the progressivity of national social security and tax systems. This framework lets us to analyze issues of intra-generational as well as inter-generational redistribution. The production technology includes heterogeneous labor inputs; i.e., labor of each skill group is a separate input into production so that each skill level earns a wage that can vary relative to those of the other skill groups. The model features six goods -- two traded and two non-traded consumer goods, a traded investment good and a non-traded public consumption good. It also features age-specific demands for consumption goods and services (e.g., healthcare).

Our simulation results suggest that the dramatic aging processes in the five regions will greatly challenge fiscal institutions leading to major increases in tax rates on labor income, via both income and payroll taxation. Despite these fiscal problems, the model predicts world-wide capital deepening due to large supplies of capital forthcoming from China and India, whose saving rates are assumed to remain relatively high over the medium term. However, since China and India are relatively highly endowed with low-skilled workers and their labor productivity is expected to catch up to that of the developed world, the model predicts a major increase over time in the relative global supply of low skilled labor, measured in effective units, which translates into major increases in wage rate inequality over the century. Excluding China and India from trade with the developed regions would prevent this growing wage-rate inequality, but come at a major cost to developed world output.

This is not the first paper to emphasize the fact that developed country workers are competing with developing country workers either directly or indirectly via their sales of goods and services. Adrian Wood (1995) provides an excellent survey of why traditional trade models can deliver the goods when it comes to explaining rising wage inequality in recent years.

The next section briefly discusses projected demographic changes in the five world regions since demographics play such a key role in the global transition path. Section III reviews the relevant literature on CGE models. Section IV presents our new CGE model, its calibration and the simulation findings. The last section concludes.

II. DEMOGRAPHIC CHANGES

Table 1 shows key demographic indicators for the U.S., EMU, NEA, China and India based on the medium variant of the United Nations population projections (UNPD, 2007) and the national population statistics provided by the Statistical Office of Taiwan (CEPD, 2007). This overview helps clarifying the differences and similarities of the demographic developments in the different world regions.

Table 1: Global demographic indicators

	Fertility rate (births per woman)		**Life expectancy at birth** (in years)		**Old-age dependency ratio** (ages 65+/ages 15-64)		**Total population** (in millions)	
	2000-05	2045-50	2000-05	2045-50	2000-05	2045-50	2000-05	2045-50
U.S.	2.05	1.85	78.2	83.1	18.4	34.0	299.8	402.4
EMU	1.50	1.85	79.7	84.3	26.3	52.9	312.2	312.9
NEA	1.53	1.73	81.2	86.7	23.4	69.8	205.6	172.6
China	1.73	1.85	73.0	79.3	10.9	38.8	1313.0	1408.8
India	2.81	1.85	64.7	75.6	8.1	21.5	1134.4	1658.3

Source: CEPD (2007), UNPD (2007).

While current fertility rates in the EMU, NEA and China are well below the reproduction rate of 2.1 births per woman, total fertility in the U.S. is very close to this level and in India fertility rates exceed the reproduction level by a considerable margin. Nevertheless the United Nations expects fertility rates in all regions to converge to 1.85 children by 2050. The total fertility rate in NEA is, however, projected to increase to only 1.73 due to the different future fertility pattern in Taiwan assumed by the Taiwanese Statistical Office.

According to these projections, mortality rates will decline in all regions over time. Consider Northeast Asia whose 2005 life expectancy at birth equaled 81.2. According to official projections, NEA's life expectancy in 2050 will reach 86.7. Due to the very high life expectancy of Japan, NEA's citizens now have a 3 year higher life expectancy than Americans and a 1.5 higher life expectancy than EMU citizens. In China, life expectancy is now 8.2 years lower than in NEA. In India, it is16.5 years lower. According to the UN projections, NEA countries will continue to maintain their longevity lead through time. Only India will reduce the gap significantly to 11.1 years in the next half century.

As one would expect, old-age dependency ratios (defined as the ratio of the population aged 65 and above to the population aged 15-64) increase in all five regions. Thanks to a high and largely rising life expectancy and only small increases over time in its fertility rate the old-age dependency ratio in NEA almost triples. By mid-century the NEA region will have the oldest population worldwide. In the EMU the share of old people will double over the same period. The U.S. population remains the youngest amongst the developed regions due to its relatively high fertility rate and more moderate reductions in mortality rates. China experiences a very rapid increase in its old-age dependency ratio, which in 2050 will exceed the year-2000 level by a factor of 3.5. In India, the aging process is more moderate. But due to the enormous rise in life expectancy, India’s old-age dependency ratio increases by 13.4 percentage points by 2050.

These changes in fertility and mortality rates obviously alter the counts of total populations. Thanks to its relatively high fertility and net immigration, the U.S. population is projected to increase from 300 million in 2005 to 402 million in 2050. In the EMU, the population remains almost stable until mid-century. In NEA, the population falls from 206 million to 173 million. The Chinese and Indian population is expected to increase. While this increase is more moderate in China (from 1.31 billion in 2005 to 1.41 billion in 2050), the population in India rises from 1.13 billion in 2005 to 1.66 billion in 2050; i.e., India becomes the most populous country in the world.

III. LITERATURE REVIEW

The development of dynamic life-cycle models was stimulated by Feldstein’s (1974) article contending that government pension systems lower national savings. Today, CGE models with overlapping generations have become the standard tools for quantifying the economic effects of demographic changes. The reasons for applying OLG models are quite obvious. On the one hand, these models treat successive cohorts separately and therefore allow for a very detailed modeling of demographic processes. On the other hand, it is possible to isolate the intergenerational distribution effects of policy reforms in this framework.

The studies of Auerbach and Kotlikoff (1987) and Auerbach et al. (1989) were one of the first calculations that quantified the fiscal and macroeconomic effects of aging populations within closed-economy frameworks. The simulation of the demographic transition paths clearly showed a dramatic increase of social security contributions and tax rates in the future. At the same time one could observe decreasing interest rates and rising wages.

Many other studies have now calculated the economic impact of aging based on the framework of Auerbach and Kotlikoff (1987), but with various extensions. Broer and Westerhout (1997), for example, include age-specific mortality rates and uncertain life span so that individual consumption and saving decisions are influenced by aging. While in their model assets are completely annuitized, others assume that people leave unintended bequests, see e.g. Kato (2002). In contrast, De Nardi et al. (1999) consider a life-long bequest motive and assume inheritances to be received over the whole life cycle. In order to account for intra-generational distribution effects of social security reforms e.g. Fehr (2000) and Beetsma et al. (2003) distinguish different productivity profiles within one specific cohort. And Nishiyama and Smetters (2005) assume heterogeneous agents to face idiosyncratic wage shocks.

These models typically focus on demographic changes in one economy modeled either as closed or small and open. However, the different timing and extent of national aging processes is expected to impact worldwide factor prices and to trigger major international capital movements with capital flowing primarily to countries with younger population structures driving up asset prices and growth. Therefore, multi-region CGE models have been developed which analyze the demographic transition in an international context. Examples are Börsch-Supan et al. (2006) and Ingenue (2007). These studies find that aging decreases the rate of return on capital.

The multi-region models of Fehr, Jokisch, and Kotlikoff (2004, 2005, 2008b) draw a different conclusion; i.e., they show that two forces lead to at least some shortage of capital (an increase in the effective supply of labor relative to capital) over time. The reasoning there is twofold. First, productivity growth can expand effective labor supplies even if the absolute number of new workers coming into the workforce is slowing or declining. Second, rising taxes needed to pay older cohorts their social security and healthcare benefits limit the saving that's done by younger cohorts.

With respect to the direction of capital flows, the models of Börsch-Supan, et al. (2006) and Fehr, et al. (2004, 2005, 2008b) do agree. During the coming decades capital will mainly flow from the rapidly aging regions of Europe and Japan to the U.S. where the aging process is much less significant. During the second half of the century capital will be repatriated from abroad.

However, these models neglect the role that fast growing developing countries will play. From our discussion in section II it is obvious that the differences in worldwide demographic changes will increase capital movements between developing and developed countries since the economies in the former regions are much younger and thus more dynamic. Therefore, Brooks (2003) applies a model with eight regions which distinguishes between three developed regions (EU, Japan, North America) and four developing regions (Eastern Europe, Africa, Latin America, China). He finds that the developed regions will export capital to the developing regions as long as the baby boom generations are in their working life. After 2030 when these generations retire and start decumulating their assets, capital will be repatriated to the developed countries.

However, Brooks (2003) assumes that the technology levels in developing countries like China remain unchanged. Other studies assume ongoing closure of the gap in per-capita incomes between the developed and developing world. Saarenheimo (2005), for example, presents a five-region model that has China and India reaching 40 percent of the European labor productivity by 2050. Given the fast aging process in China, this assumption has only minor effects on developed world's capital flows.

Aglietta, et al. (2007) consider different rates of Asian catch up. They find that China will improve its current account dramatically between 2030 and 2050 if they catch-up to total factor productivity in North America by 2100. In their model North America is the largest supplier of capital in the medium and long run since they adjust American saving behavior to levels observed in other developed regions. Finally, Fehr et al. (2007) show that not only technology growth matters to international capital movements, but also the future saving behavior of the Chinese population. If China maintains its very high saving rate in the future it could become the developed world's major supplier of capital in the medium run.

These studies give very important insights in how demographic changes might affect international capital movements. What they miss is the fact that the demographic developments together with the dramatic economic growth of Asian regions will also have a major impact on production structures and international commodity trade. Only the studies of Aglietta et al. (2007) and Ingenue (2007) account for international commodity trade. But they don't distinguish the production of different consumption goods and do not account for the fact that production sectors vary heavily with respect to the skill structure employed in the different sectors. Moreover, their models cannot distinguish between skill-specific wages. And finally, their models do not capture age-specific demand of different consumption goods in household's utility.

IV. CGE-MODEL OF DEMOGRAPHIC TRANSITION WITH GLOBAL TRADE

(i) Model overview

Our new CGE model with overlapping generations builds on previous work in Fehr et al. (2007). A detailed description can be found in Fehr et al. (2008a). The model covers five different world regions, namely the U.S., the EMU, NEA, China and India.

We incorporate a rich demographic structure according to the population forecasts discussed in section II. Agents in each region live at most to age 90. Consequently, there are 91 generations with surviving members at any point in time. 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.

Immigration is treated as exogenous, again based on current and forecasted patterns. 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.

The model's preference structure is represented by a time-separable, nested, CES utility function where remaining lifetime utility is composed of the agent's utility from her/his own goods and leisure consumption and the agent's utility from the consumption of her/his children. The latter assumption delivers the hump in the consumption profile appearing during child-rearing years in actual data. The aggregate consumption good is a Cobb-Douglas composite of four different consumption goods (services, housing, low-tech good, high-tech good). The shares of these different goods in aggregate consumption are assumed to vary with age. Thus our model can accommodate age-related changes in, for example, demand for medical services. Since lifespan is uncertain, the utility of consumption in future periods is weighted by the survival probability.

Agents earn gross labor income derived as the product of their labor supply and wage rate. The latter is the product of the skill-specific wage rate and the age- and year-specific earnings ability. In each year agents also receive inheritances where we assume 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. Households have to pay net taxes which 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.

As in Kotlikoff et al. (2007), we model technical progress as permitting successive generations to use time more effectively, whether in working or enjoying leisure. 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.

Given price indices, interest rates and wages agents maximize utility subject to the intertemporal budget constraint and the constraint that leisure in each period not exceeds the time endowment. They do this by choosing their leisure and consumption demands.

In every period each region produces six different goods (services, housing, low-tech good, high-tech good, investment good, public good). Aggregate output of each good is produced via a Cobb-Douglas technology that uses capital and skill-specific labor. Profit maximization requires the interest rate to equal the marginal product of capital and the skill-specific wage rates to equal the marginal product of skill-specific labor.

Each region's government issues additional debt and collects taxes to finance general government expenditures, those pension, healthcare, and disability benefits that are general-revenue financed, and interest on existing debt. We assume that each government maintains its initial debt-to-output ratio over time. The progressivity of wage taxation is modelled after Auerbach and Kotlikoff (1987), with marginal wage tax rates rising linearly with the wage-tax base.

In each region we distinguish three different pay-as-you-go social security systems; that is a public pension system, health and disability insurance. Pension benefits are assumed to depend linearly on the agent's average earnings during her working life. The region-specific parameters for the replacement rates in the U.S., the EMU and NEA were chosen to match replacement rates reported in OECD (2007c). 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 e.g. World Bank, 2005). Since we cannot 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. Health outlays are age-specific and disability benefits are provided as uniform per-capita transfers.

Average payroll tax rates 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. In China and India disability insurance provisions is handled by state pension systems and these systems don’t separate disability and pension payments in their reporting. Hence, for these countries, the disabilty benefit payroll tax rate is set to zero, and the pension benefit payroll tax rate finances both types of benefits. Due to contribution ceilings, individual pension, disability, and health-insurance 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 pension payroll taxes and, in the EMU, NEA, China and India, health-insurance payroll taxes, up to the relevant ceilings, but face no payroll taxation at the margin. The other earnings classes are assumed to face the full statutory tax rate on all their earnings. The disability payroll taxes in the U.S., the EMU and NEA are modeled in an equivalent manner. However, since there is no ceiling on U.S. Medicare taxes, all skill groups in the U.S. face the health-insurance payroll tax at the margin.

General government expenditures consist of government purchases of goods and services, including educational expenditures and health outlays. Over the transition, the ratio of general government purchases of goods and services to GDP is held fixed. Age-specific per-capita education and disability outlays are assumed to grow with GDP per capita over the transition. 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. As shown in Hagist and Kotlikoff (2009), this is a rather conservative assumption concerning future growth in benefit levels. 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.

We keep the ratio of wage-tax to consumption-tax revenue fixed during the transition and balance the government's annual budget by adjusting the intercept in our linear equation determining the average wage-tax rate as well as the consumption-tax rate.

To compute the world economy's perfect-foresight general equilibrium transition path, we start with initial guesses of the equilibrium factor and product prices. We next use these prices to determine consumption demands and supplies of both labor and assets for each year in each region. We assume that services and housing as well as the public good are non-traded goods and that the low-tech and high-tech good as well as the investment good are traded. Equilibrium in the traded goods market requires that world output equals world demand.

Factor demands in the non-traded sectors in each region are determined by the first-order conditions from profit maximization. From the equilibrium condition of world factor markets we reach world-wide excess supplies of labor and capital available for productive use in the traded sectors given the world-wide demands for these factors to produce non-traded goods. These excess supplies of inputs available to produce traded goods must equal their respective world-wide demands by traded goods producers.

Given the excess supplies of inputs we can calculate the capital and labor input-output coefficients in the investment good sector for every period and update our guesses of wages and interest rates. Note that the producer price of the investment good is normalized to unity. Given the new factor prices we compute the capital and labor input-output coefficients in the remaining production sectors and thus can derive producer prices for private and public consumption goods which measure the unit cost of production as the product of input prices and their usage per unit of output.

We next use the factor input-output ratios and the total output of traded goods to allocate production to the different regions. Doing so lets us determine the regional pattern of net exports. Our procedure is to first derive, for each year and the three productivity levels, the excess labor supply in each region available for use in the three traded goods. We then relate these excess labor supplies to their respective excess labor demands; in so doing, we arrive at three equations in three unknowns, which we use to determine the share of worldwide production of each of the traded goods in each region. Given the share of world-wide supply of each traded good that is being produced in a specific region, we can determine the factor inputs in the traded goods sectors in each region.

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. It converges very tightly around the equilibrium transition path.

(ii) Calibration

In the following we only give an overview of the most important assumptions of the model calibration. For a detailed discussion see Fehr et al. (2008a). As already mentioned above, our model implements a very detailed demographic structure and development for the five regions with population projections starting in the year 2000. 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 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 official population projections until 2050. Afterwards, fertility rates are endogenously adjusted in line with zero population growth and a stable population age structure. Assuming that the adjustments of fertility rates to achieve what is ultimately stable populations occur later in time will not materially alter how the global economy performs over the first half of this century.

Each cohort in our model is split into three skill classes (low, middle, high). We assume that 15 percent of each cohort belongs 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 findings reported by 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 belongs to the lowest, 25 percent to the top skill class, and 53 percent to the middle.

On first consideration, the share of the lowest skilled class might seem low. 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 no education at all. Thus we may understate the number of low-skilled workers in these regions. However, in our calibration we target relative wage rates for the three income classes in the initial year based on earnings dispersions reported in OECD (2008), and can match up with the OECD findings only by making these assumptions about the relative sizes of the three skill groups in the five regions.

Table 2: Production technology parameters

	Services	Housing	Low-tech good	High-tech good	Investment good	Public good
Capital share in production	0.26	0.57	0.44	0.41	0.35	0.26
Share of specific labor inputs						
Low-skill	0.08	0.11	0.15	0.03	0.06	0.02
Medium-skill	0.57	0.62	0.58	0.38	0.57	0.39
High-skill	0.35	0.27	0.27	0.59	0.37	0.59

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 high in the housing sector; they are low in the private service and public goods sectors. 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.

Table 3 reports values of preference and policy parameters. The time-preference rates (which determine how impatient households are when it comes to consuming now versus in the future) in the five regions were set to match the model's 2005 ratios of private consumption to GDP to the region-specific values. The U.S., EMU, and NEA time-preference rates are held fixed through time. But in line with our baseline assumption that the Chinese and Indian public will eventually adopt developed economies' spending habits, we gradually raise the time preference rate of successive Chinese and Indian cohorts so that the cohorts that reach adulthood (age 21) in 2030 and thereafter have the same time-invariant time-preference rate as in the U.S.   I.e., we assume that the Chinese and Indians gradually become more impatient when they consider whether to spend now or save in order to spend in the future.

The intertemporal elasticity of substitution, the elasticity of substitution between consumption and leisure, and the leisure preference parameters are taken from Kotlikoff, et al. (2007). 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 services' share rising considerably with age.

The age- and year-specific earnings ability profile is taken from Auerbach and Kotlikoff (1987). The earnings-ability profile simply specifies how much a worker's productivity changes as he/she ages and gains more experience on the job. Note that we assume that the higher is the rate of technological change, 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. Intuitively, workers experience become more productive as they age due to learning on the job. This continues up to a point when physical wear and tear sets in. But in addition to this worker-specific variation of productivity with age, there is another force, namely economy-wide productivity growth, that helps a worker produce more for the same labor input. This economy-wide productivity growth, like on-the-job-learning (also called learning by doing), makes workers more productive the older they are because they benefit from the cumulative amount of economy-wide productivity that it occurring over time.

Table 3: Preference, productivity and policy parameters

	U.S.	EMU	NEA	China	India
Time preference rate	0.02	0.02	0.02	-0.10	-0.04
Labor productivity parameter	1.00	0.65	0.50	0.018	0.01

Consumption shares of goods	Services	Housing	Low-tech good	High-tech good
ages 25 and below	0.04	0.36	0.19	0.41
ages 25 to 34	0.06	0.40	0.17	0.37
ages 35 to 44	0.07	0.40	0.18	0.35
ages 45 to 54	0.08	0.38	0.17	0.37
ages 55 to 64	0.11	0.38	0.17	0.34
ages 65 to 74	0.16	0.38	0.16	0.30
ages 75 and above	0.21	0.40	0.15	0.24

We normalize the labor-productivity parameter 1.0 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 this adjustment 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 1.0, entering in the determination of their labor productivity.

Intuitively, this labor-productivity parameter is capturing the Chinese and Indian catching up process. The model, for example, treats Chinese low-, middle-, and high-skilled workers as only 1.8 percent as productive as their American counterparts in the initial year, 2005. But, over time, the model assumes that successive cohorts will be better educated and become as productive, within their skilled ground, as Americans in those same skill groups. Stated differently, in assuming that Chinese workers are initially only 1.8 percent as productive as American workers within the same skill class, we are also assuming that it takes 1 divided by .018 Chinese workers to do the same work as 1 American (assuming they are in the same skill category).

Note that Chinese workers who work the same number of hours as Americans will be paid less until their productivity catches up with that of Americans. But they will receive the same wage per unit of effective time, where a unit of effective time is the amount of time it takes them to produce what an American can produce in, say, an hour. Thus if it takes a Chinese worker 5 hours to produce what an American can produce in 1 hour, the Chinese will earn the same for the 5 hours as the American will earn for working 1 hour.

(iii) Findings

Initial equilibrium and baseline transition path

We first report our baseline transition path findings[1] starting with the comparison of simulated with observed 2005 macro variables. The official GDP figures presented on the right side of Table 4 are taken from European Commission (2007, 2008), and, for India, OECD (2007a). 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).

Table 4: The year 2005 of the baseline path

	Model					**Official**				
	U.S.	**EMU**	**NEA**	**China**	**India**	**U.S.**	**EMU**	**NEA**	**China**	**India**
Private consumption	70.6	57.7	57.4	39.1	58.6	70.4	57.4	57.0	38.0	58.5
Government expenditures	15.8	20.5	18.1	13.9	11.5	15.9	20.5	18.1	13.9	11.5
Domestic investment	21.2	19.1	17.7	35.0	32.5	19.1	20.6	23.3	42.6	31.6
Trade balance	-7.6	2.7	6.8	11.9	-2.6	-5.8	1.4	1.4	5.5	-1.6
Current account	0.1	0.0	4.1	-4.2	-16.2	-5.9	0.1	3.6	4.0	-3.0
Relative GDP levels	1.00	0.86	0.47	0.19	0.08	1.00	0.81	0.46	0.18	0.06
Social benefits	14.2	20.6	16.6	4.0	3.5	14.3	20.7	16.5	4.0	-
Pension benefits	6.2	11.1	9.4	3.2	2.7	6.3	11.2	9.3	-	-
Health benefits	6.8	7.4	6.5	0.7	0.8	6.8	7.4	6.5	0.6	-
Disability benefits	1.2	2.0	0.7	-	-	1.2	2.1	0.7	-	-
Pension contribution rate	10.6	14.8	16.9	5.5	4.7	10.6	-	14.6	28.0	29.6
Healtcare contribution rate	2.9	9.9	8.8	1.2	1.4	2.9	-	8.2	8.0	6.5
Disability insurance contribution rate	2.0	2.7	1.3	-	-	1.9	-	-	-	-

[1] Our baseline path includes the UNPD's (2007) assumption of increasing fertility rates in EMU, NEA and China. However, since such large increases of fertility over the coming decades are hard to believe, we reran the baseline path assuming constant fertility rates in these three regions over time. As our simulation results suggest, this assumption has only a very small impact on future factor prices changes. The main effect is on the growth of the macroeconomic variables which is considerably dampened during the transition.

Our model's trade balances agree in sign, but not value, with actual levels. 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 (2007b, c, d). 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. 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, trade balances, and average 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 3.5, and NEA GDP expands by a factor of only 2.8. 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 2030. But once China's productivity levels reach U.S. values, its growth slows. Consequently, by 2100, China's GDP is only 1.9 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 2.4 times U.S. GDP and 1.2 times China's. Together, China and India account for 4.3 times U.S. GDP in 2100, and U.S. GDP, which accounts for 38.5 percent of total 5-region GDP in 2005, accounts for only 16.0 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. The key points of interest are the very rapid expansions of labor supply in China between 2005 and 2030 and in India between 2050 and 2100.

Over the first 25 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 the U.S. runs such large trade surpluses toward the end of the century and why China runs such large trade deficits. The table also shows that trade deficits and surpluses can be very sizeable for decades before they reverse their sign and that their pattern is not easily forecast. I.e., there are a host of complex, interconnected factors determining their time paths including inter-regional differences in saving behavior, demographics, and fiscal policies.

Consider next how average tax rates evolve. Obviously, the developed regions experience dramatic increases over time in tax rates. Their development is due to 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 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.

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

Year	GDP	Capital stock	Labor demand			Trade balance /GDP*	Payroll tax*	Wage tax*	Consump-tion tax*
			low	middle	high				
U.S.									
2005	1.00	1.00	1.00	1.00	1.00	-7.6	15.5	13.4	11.1
2030	1.63	1.71	1.60	1.56	1.65	-9.4	24.6	17.2	15.2
2050	2.76	3.08	2.79	2.54	2.65	11.1	22.6	19.6	24.8
2100	4.61	4.55	5.11	4.56	4.67	14.5	28.4	20.3	25.0
EMU									
2005	0.86	0.83	0.73	0.83	0.97	2.7	27.5	11.9	22.9
2030	1.30	1.33	1.14	1.19	1.43	0.0	40.1	12.4	25.0
2050	1.96	2.17	1.81	1.73	2.01	12.6	39.7	13.3	35.7
2100	3.01	2.93	3.06	2.87	3.23	14.5	39.9	14.0	35.9
NEA									
2005	0.47	0.46	0.39	0.46	0.53	6.8	27.0	14.3	20.7
2030	0.73	0.74	0.69	0.71	0.77	2.4	35.6	14.3	21.5
2050	1.02	1.13	1.04	0.95	0.99	8.8	36.2	15.0	26.3
2100	1.31	1.30	1.51	1.30	1.30	1.4	35.5	16.1	22.0
China									
2005	0.19	0.19	0.19	0.18	0.20	11.9	6.7	4.0	29.4
2030	2.96	3.21	3.72	2.85	2.71	4.0	5.4	3.6	20.0
2050	5.27	6.57	7.81	4.83	4.04	-18.7	11.4	3.5	13.4
2100	8.88	9.61	13.38	8.71	7.54	-10.8	23.9	4.0	15.4
India									
2005	0.08	0.08	0.08	0.07	0.08	-2.6	6.1	4.0	19.1
2030	1.29	1.39	1.40	1.21	1.25	1.2	4.6	3.1	18.0
2050	4.12	4.86	4.71	3.76	3.67	8.3	8.5	3.3	20.0
2100	11.04	11.92	16.32	10.82	9.43	-1.5	20.6	4.2	17.7

* in percent

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.

Changes in factor prices are shown in Table 6[2]. As in Fehr et. al. (2007), the interest rate decreases through mid-century thanks in large part to China's extremely high propensity to save. In the second half of the century it increases again, but ends up in 2100 some 120 basis points below the year-2005 value.

Table 6: Factor prices in the baseline path

Year	Interest rate	Wage rates*		
		low	middle	high
2005	12.5	1.00	2.99	5.83
2030	10.9	0.84	3.13	6.37
2050	9.1	0.75	3.24	7.16
2100	11.5	0.68	2.97	6.86

* at age 21 per unit of effective time

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 75 percent of the year-2005 level; in 2100 it is only 68 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 through mid-century; in 2050, it is 23 percent above its initial value. After 2050, the high-skilled wage rate falls, stabilizing in 2075 at 18 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 5.83. By 2050 this factor is 9.5. In 2100 the factor is 10.1! Our model also generates significant changes in the region-specific structure of production during the transition. For a detailed discussion of these patterns see Fehr et al. (2008a).

Eliminating trade with China and India

We explore next 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

[2] The simulation results in the baseline transition path assume constant income-class shares on the national levels. Of course, it has to be expected that these shares react over time due to the predicted changes in relative wages and education policies, especially in the case of China and India. In order to test the sensitivity of our simulation results to changes in the skill structure in the developing countries and since our model does not allow for endogenous switches between skill classes, we ran a simulation that gradually adjusts the skill shares of new workers in China and India to those in the developed regions within 30 years. As expected, the relative price effects found in our baseline transition path are mitigated to a large extent and wage inequality remains roughly constant over time. The detailed simulation results of this scenario are reported in Fehr, et al. (2008a).

model. The calibration of the remaining regions remains unchanged. Table 7 reports macroeconomic variables. Note that we express all indexes relative to the U.S. year-2005 levels of the baseline path.

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 years of the transition are higher compared to the five-region case since more capital now remains in the developed world. For example, in 2020 the capital stock index in the U.S. is 1.46 compared to 1.27 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. These developments are also reflected in the path for payroll tax rates. These rates increase to a larger extent in the medium run. In the short and long run they are below their respective baseline values.

The most interesting finding of excluding China and India is its impact on the wage structure, see Table 8. 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 95 percent of the year-2005 level; it was 68 percent of the year-2005 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 2.5 percent below its 2005 level compared to 18 percent above its 2005 level when China and India are included.

Table 7: Simulation results of the transition path without China and India

Year	GDP	Capital stock	Labor demand			Trade balance /GDP*	Payroll tax*	Wage tax*	Consump-tion tax*
			Low	middle	high				
U.S.									
2005	1.02	1.06	0.98	1.00	1.00	-6.6	15.4	13.2	11.1
2030	1.59	1.65	1.46	1.52	1.65	-4.5	24.8	16.9	14.9
2050	2.18	2.13	2.03	2.16	2.34	-0.6	24.9	17.7	16.8
2100	3.96	3.82	3.66	3.91	4.29	1.6	28.7	18.1	17.5
EMU									
2005	0.88	0.88	0.71	0.83	0.96	3.4	27.3	11.7	22.8
2030	1.25	1.27	1.01	1.16	1.43	3.5	39.4	12.3	24.6
2050	1.59	1.52	1.34	1.51	1.84	3.5	40.5	12.8	25.8
2100	2.62	2.48	2.21	2.51	3.07	4.5	39.1	13.0	26.9
NEA									
2005	0.48	0.49	0.39	0.46	0.53	7.8	26.8	14.0	20.5
2030	0.68	0.68	0.58	0.67	0.75	4.1	34.4	14.2	20.8
2050	0.81	0.77	0.74	0.81	0.86	-5.3	35.9	14.9	18.9
2100	1.12	1.08	1.03	1.12	1.20	-16.3	35.1	14.7	15.8

* in percent

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 14 percent. Total developed region GDP is reduced by 17 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.

Table 8: Factor prices without China and India

Year	Interest rate	Wage rates*		
		low	middle	high
2005	11.9	1.05	3.04	5.96
2030	11.7	1.04	3.08	5.95
2050	12.7	0.99	2.98	5.87
2100	12.8	1.00	2.98	5.81

* at age 21 per unit of effective time

V. CONCLUSION

This paper presented a new five-region, dynamic, general equilibrium, life-cycle model to analyze the impact of the Asian economic boom on the developed world's demographic/fiscal transition path, and 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 spells portends further dramatic increases in wage rate inequality over the century.

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. 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 over the medium term.

Excluding China and India from trade with the developed regions succeeds in limiting wage-rate inequality. It does so by preventing the Chinese and Indians from bringing into the market ever larger numbers of workers who are disproportionately low-skilled. 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 17 percent compared with the case of free trade. It also reduces capital intensivity (capital per worker of equal productivity), raising the long-run real interest rate by 90 basis points. 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 2.5 percent lower rather than 23 percent higher.

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.

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