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The global implications of freer skilled migration*

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The global implications of freer skilled migration

Abstract:

One consequence of the trade and technology driven increases in skill premia in the older industrial regions since the 1980s has been a perceived "skill shortage" in those regions, along with freer migration of skilled and professional workers from developing regions. While skilled migration flows remain too small to have large short-run effects on labour markets, a further opening to skilled migrants by the industrialised North could see substantial changes in labour markets and overall growth performance. The links between demographic change, migration flows and growth performance are here explored using a new demographic sub-model that is integrated with an adaptation of the *GTAP-Dynamic* global economic model in which regional households are disaggregated by age and gender. Skilled migration flows are assumed to be motivated by real wage differences to an extent that is variably constrained by immigration policies. A uniform relaxation of these constraints has most effect on labour markets in the traditional migrant destinations, Australia, Western Europe and North America, where it restrains the skill premium and substantially enhances GDP growth. The skill premium is raised, however, in regions of origin, and particularly in South Asia, although the extent of this is shown to depend sensitively on the responsiveness of skill acquisition to regional skill premia.

1. Introduction

Rising skill premia in industrial labour markets in the 1980s and 90s sparked a substantial literature on the effects of expanded trade with developing regions and the development and transmission of skill-using technological change.[1] These changes have coincided with declining fertility in the older industrialised regions and a transition in Europe and Japan to labour force decline.[2] They are further complicated by even more rapid fertility decline amongst educated families, from whence emerge the children with the greatest potential for skill-acquisition.[3] Taken together, these trends have brought forth "skill shortages" in those regions, along with policy changes that have allowed freer migration of skilled and professional workers from developing regions.

While skilled migration flows remain too small to have large short-run effects on labour markets, a continued opening to skilled migrants by the industrialised North could see substantial changes in labour markets and overall growth performance. In this paper the links between demographic change, migration flows and growth performance are explored using a new demographic sub-model that is integrated with an adaptation of the *GTAP-Dynamic* model of the global economy, in which regional households are disaggregated by age and gender. Skilled migration flows are assumed to be motivated by real wage differences to an

[1] See McDougall and Tyers (1997), Berman, Bound and Machin (1998) and Tyers et al. (1999).
[2] See Bongaarts and Bulatao (2000), McDonald and Kippen (2001), Lee (2003).
[3] **** Papers that establish that educated fertility decline has been faster.

extent that is variably constrained by immigration policies. A uniform relaxation of these constraints has most effect on labour markets in the traditional migrant destinations, Australia, Western Europe and North America, where it restrains the skill premium and substantially enhances GDP growth. The skill premium is raised, however, in regions of origin, and particularly in South Asia, although the extent of this is shown to depend sensitively on the responsiveness of skill acquisition to regional skill premia.

The paper is organised as follows. Section 2 discusses the construction of the matrices of inter-regional migration flows that are essential to the modelling. Wage divergences that motivate migrants are then discussed in Section 3 and the full demographic and economic models used are described in Section 4. Next, the preparation of a base line projection for the global economy that incorporates full demographic change is discussed in Section 5. This projection is compared in Section 6 with others that allow more responsiveness to real wage divergences. Conclusions are then offered in Section 7.

2. Constructing the Initial Global Migration Flow Matrix

Migration records are incomplete and inconsistent across countries and this has frustrated past attempts to construct complete matrices of international movements. Important progress is being made by Parsons, Skeldon, Walmsley and Winters (2005), who present migrant stocks for 226 countries of both origin and destination. They rely primarily on census data, so that countries of origin are determined for the foreign born as countries of birth. These data are complemented by those on nationality, which is treated analogously to citizenship. The use of the UN definition of a migrant[4] for collated data means that only permanent movements of natural persons are considered in their analysis.

Migration Statistics

In addition to the national census, Parsons et al. also rely on associated labour force surveys, which typically include questions about the nationality and place of birth of the respondents. The measurement of migrant populations based on census information facilitates greater comparability of statistics across countries because of the limited scope of the questions asked. Drawbacks are that censuses are infrequently conducted, with “rounds” that usually span a decade, and each country carries out its survey at different times. Also there is a tendency to under-represent migrants who may not be registered for census purposes.

[4] UN (1998) definition of a migrant is “any person who changes his or her country of usual residence”.

Parsons et al. (2005) also use data from population registers, which are accounts of the domestic and foreign population within a country. They are generally maintained via a legal obligation for all persons to register themselves with the appropriate local authorities. Registers provide information more frequently than censuses but since not all departures are recorded outflow data is less reliable and there are differences in the type of migrants counted which must be taken into account when directly comparing data from different countries. In general, immigrant stock statistics contain a high degree of cross-country heterogeneity from unavoidable inaccuracies associated with both individual countries' practices for gathering census and survey data and the approaches used in identifying both legal and illegal immigrants.[5].

The Migration Stock Matrix

We begin by constructing an accessible aggregation of the world into just 14 regions (Appendix 1). The first step in generating annual migration flows between these 14 regions is to develop a 14 by 14 matrix of migrant stocks. For this we rely on Parsons et al. (2005). Because the "continental" aggregation that has been made available from their study differs from ours a weighting system proved necessary. Weights were derived by firstly calculating the total migrant stock in each of the 14 regions as well as in the Parsons et al. continents, using UN migration stock data for the year 2000 (UN, 2002). The regional proportion of migrants in the continent then emerges by dividing by the migrant stock in each continent. The stock of migrants in region d from region r, $Stock_{rd}$, is thus:

$$(1) \qquad Stock_{rd} = \frac{Stock_d \times Stock_{c(d)c(r)}}{\sum_{c(r)} Stock_{c(d)c(r)}}$$

where $Stock_d$ is the migrant stock in d obtained from UN data, $Stock_{c(d)c(r)}$ is the migrant stock from continent c that contains region r to the continent that contains region d and the denominator is the sum of migrants from all origins in the considered continent.

The Migration Flow Matrix

Annual flows of migrants to Australia, North America and Western Europe from the 14 regions were obtained from Chan and Tyers (2004) with some adjustments to the Australian data based on Department of Immigration and Multicultural Affairs (2001). These regions maintain and publish comparatively complete and accurate immigration records. We

[5] For example, developed countries generally include refugees in their censuses while their less developed counterparts do not.

therefore used them to investigate the relationship between flow and stock data. The ratio of migrant flows to stocks was first calculated, as shown in Table 1, from which it can be seen that the ratios vary significantly across the destinations for each source region. As flow data for the remaining 11 regions is not readily or reliably available the average ratios for each region of origin were applied to the stock matrix to produce the resulting matrix of migration flows, presented in Table 2.

The largest source of global migration is the region “Central Europe and the Former Soviet Union” whose emigrants prefer to settle in Western Europe. The next largest source of immigrants is the “Rest of the World” grouping, whose emigrants tend to settle in North America and Western Europe. The Central Europe and Former Soviet Union bloc is also the third most popular destination for migrants, following Western Europe and North America respectively, with 22 per cent of the Central Europe and the Former Soviet Union immigrant intake coming from Sub-Saharan Africa.

Australia has the largest volume of immigrants by comparison with its population. The majority of these appear to come from the “Rest of the World” bloc, which includes New Zealand, though Western Europeans account for 20 per cent of Australian annual immigration with Chinese and Other East Asians each providing roughly 10 per cent. On the other hand, 59 per cent of Australian emigration flows are to North America and Western Europe, approximately 13 per cent of Australian migrants go to Central Europe and the Former Soviet Union while Asia attracts 8 per cent of the Australian migrants with the largest flows being to India and Other South Asia. Indonesia is the least attractive destination region for Australians with only 60 people migrating there annually.

Regions with net annual immigration, as shown in Figure 1, are Western Europe, North America, Australia, Middle East and North Africa, and Japan, in descending order of volumes. All the remaining regions have net annual emigration rates with the Rest of the World providing the largest source of migrants and Indonesia the least.

Migration Flows by Age and Gender

Detailed accounts of both the regional and the age-gender compositions of immigrant flows are unavailable for most countries and regions. A comprehensive breakdown is available for the United States, however, via the US Citizenship and Immigration Services (USCIS, 2001)[6]. It is therefore assumed that the age-gender composition of all migrant flows matches that of immigrants to the United States. By firstly summing the total immigrant

[6] Thanks are due to Prof. Tim Hatton of the Australian National University for directing the author to these data.

population of each group for the years 1986 to 2001, the migrant population share of each group was derived. These shares were then applied to the aggregate flow matrix of Table 2 to derive a set of eight matrices that detail the migrant flows between regions for each age-gender group. Thus the annual migration flow *rate* for age group *a*, gender *g*, from the region of origin *r* and to the destination in region *d* can be expressed algebraically as:

$$(2) \qquad M^R_{a,g,r,d} = \frac{M_{r,d}}{N_{a,g,d}} \left(\frac{\sum_r M_{a,g,r,d=NthAmerica}}{\sum_r \sum_{a=014}^{60+} \sum_{g=m}^{f} M_{a,g,r,d=NthAmerica}} \right)$$

where $M^R_{a,g,r,d}$ is the annual migration flow *rate* between *r* and *d* expressed as a proportion of the region *d*'s group population, $N_{a,g,d}$. The variable $M_{r,d}$ represents the *total* flow of migrants from *r* to *d* in Table 2 and $M_{a,g,d=NthAmerica}$ is the age and gender specific flow of immigrants to North America.

3. The Incentive to Migrate - Regional Real Wage Differences

Regional wage inequality stems from differences in labour productivity associated with different relative factor abundance and technology, combined with trade and migration restrictions (Tokarik, 2002; Kar and Beladi, 2002). Trade liberalisation, along with the associated competition from lower-waged countries, has reduced demand for unskilled labour in developed countries while simultaneously increasing demand for skilled workers. This has tended to drive a greater wedge between the wage rates of skilled and unskilled workforces. Conversely, Kar and Beladi (2002) have noted that empirical evidence suggests a narrowing of the wage gap between the two skill levels in developing regions. Wage inequality can also be related to international migration. Most migration, as indicated in the previous section, is from less developed regions to the OECD countries. These migrants possess varying levels of human capital which affect the wage and employment patterns of both the source and destination region by changing the distribution of labour and (human) capital.

Skilled and Unskilled Labour Payments

The key resource for this analysis is the GTAP global database. In it, skills are defined based ILO occupational categories (Liu et al. 1998). Labour is split into two levels:

unskilled (production) labour and skilled (professional) labour. Skilled labour therefore incorporates occupations[7] requiring advanced training beyond secondary education.

Market Exchange Rate Wages

Calculation of skilled and unskilled wages per worker firstly requires data for the total full time equivalent labour force over age, gender and skill level in each region. Labour force numbers by age and gender were obtained from Chan and Tyers (2004) for the year 1997. Labour force shares of skilled workers were then obtained from Liu et al. for each GTAP-defined region, and then aggregated to the 14 applied here.

The GTAP database does not offer volume statistics for primary factor inputs. It does, however, provide total payments to each of the two types of labour, denominated in US dollars at market exchange rates (*MER*). Wage rates in region *r* for skill level *s*, used for the purpose of this analysis were firms' purchases at agents' prices, $EVFA_{s,r}$, which had been calculated as expenditure on labour by firms across all sectors. Thus the 1997 US$ annual wage per worker, *w*, in region *r* for skill *s* was derived via:

$$(3) \qquad w^{MER}_{s=skilled,r} = \frac{EVFA_{s=skilled,r}}{\sum_{a=1539}^{60+} \sum_{g=m}^{f} L_{a,g,r} S_{a,g,r}}, \qquad w^{MER}_{s=unskilled,r} = \frac{EVFA_{s=unskilled,r}}{\sum_{a=1539}^{60+} \sum_{g=m}^{f} L_{a,g,r} (1 - S_{a,g,r})}$$

where for age *a* and gender *g* $L_{a,g,r}$ is the size of the full time equivalent labour force and $S_{a,g,r}$ is the volume share of skilled labour. The resulting rates are listed in Table 3 and plotted in Figure 2.

These results indicate that the US$ rewards to workers in 1997 were highest in the industrialised regions while developing regions, typically with higher population densities, have lower wages for both skilled and unskilled workers. There are also significant wage differences between the skill levels for all regions with skilled workers earning consistently more than their unskilled counterparts[8]. The lowest wage rate for the unskilled was in the Indian and Other South Asian regions with workers earning roughly US$350 per year, while Japan offered its unskilled labour the largest unskilled reward at a rate of US$32449 per year. North America and Japan payed skilled workers the highest wage at more than US$43000 per

[7] "Skilled" occupations include managers, professionals, engineers, scientists and bureaucrats, to list a few (Hertel, 1997). Unskilled workers are defined to include as tradespersons, teachers, clerks, sales assistants, industrial workers and farm hands (Liu et al, 1998).

[8] This is with the exception of Central Europe and the Former Soviet Union which appears to have had slightly larger returns to unskilled labour. This is very likely a statistical aberration due to inaccurate national accounts data on labour payments.

year whereas India offered its skilled workers the lowest skilled compensation at an average wage of approximately US$650 per year.

The implicit assumption behind the assembly of the GTAP global database is that the purchasing power of one US$ is equal in all regions. For most applications departures from this assumption do little harm. In considering migration inducement, however, the fact that the prices of non-tradables in developing countries are lower than in industrial countries implies that the purchasing power of a US$ is higher in the developing countries. Since inducement to migrate depends at least in part on the real purchasing power of wages in destination and origin regions, errors in *MER*-based projections of real wages tend to overestimate the migration response. Purchasing power parity (PPP) derived wages would more reliably reflect the true distribution because they would incorporate, at least partly, a more realistic valuation of non-traded goods and services.

Purchasing Power Parity Wages

In order to compare the real purchasing power of wages across regions, the market exchange rate results in Table 3 were converted into approximate purchasing power parity results using a multiplier derived the Global Development Network Database (World Bank, 2001). This multiplier is the ratio of the MER-based GDP estimate in US$ to the corresponding PPP estimate, by country in 1997[9]. This was used to calculate the PPP multiplier for that year, α_r^{PM}, on the 14 defined regions, by aggregating individual countries according to MER-based GDP shares. The PPP wage estimates are therefore:

(4) $$w_{s,r}^{PPP} = w_{s,r}^{MER}\alpha_r^{PM} \text{, where } \alpha_r^{PPP.MER} = \sum_{i \in r}\left(\frac{GDP_i^{PPP}}{GDP_i^{MER}} \cdot \frac{GDP_i^{MER}}{\sum_{j \in r} GDP_j^{MER}}\right),$$

and GDP_i^{PPP} and GDP_i^{MER} represent, respectively, the GDP corresponding to purchasing power parity and market exchange rate values in country *i*.

PPP wage results are also shown in Figure 2 and Table 3. They indicate a smaller wage range across regions for both skilled and unskilled workers when compared with MER values. The coefficient of variation for unskilled wages per worker decreased from the MER ratio of 1.32 to 0.97 when using PPP. Similarly, the PPP skilled wage rate also had a reduced coefficient of variation, down from the MER value of 1.11 to 0.80. Average regional wages increased by approximately US$619.93 for unskilled workers and US$3,478.83 for skilled

[9] Thanks are due to Prof. Steve Dowrick of the Australian National University for directing the authors to these data.

workers. In developing regions, average wages rose for unskilled workers from US$1,845.8 to US$3,984.2 and skilled workers from US$5274.3 to US$12913.7 per annum.

Consistent with MER-based wages, PPP measures exhibit higher wages in the more highly developed regions. The single exception is the PPP skilled wage in Sub-Saharan Africa, which appears to surpass even that of Japan. Generally, PPP wage rates in all developing regions are higher while those of Australia, Japan and Western Europe are lower. On the other hand North America, largely a developed region, has higher PPP wages. One plausible explanation for this apparent anomaly is the inclusion of Mexico in the region, which accounts for approximately 9% of the North American PPP multiplier[10] and itself has a PPP to MER GDP ratio of 1.95. India has the largest PPP multiplier with a value of 3.81, followed by China which has a PPP multiplier of 3.71. Sub-Saharan Africa, with a multiplier of 2.85, follows Indonesia and Other South Asia which have PPP multipliers of in the vicinity of 3.0.

4. Modelling Global Economic and Demographic Change

The approach adopted follows Tyers et al. (2005), in that it applies a complete demographic sub-model that is integrated within a dynamic numerical model of the global economy.[11] The economic model is a development of *GTAP-Dynamic*, the standard version of which has single households in each region and therefore no demographic structure.[12] The version used has regional households that are disaggregated by age group, gender and skill level.

4.1 Demography:

The demographic sub-model tracks populations in four age groups and two genders: a total of 8 population groups in each of 14 regions.[13] The four age groups are the dependent young, adults of fertile and working age, older working adults and the mostly-retired over 60s. The resulting age-gender structure is displayed in Figure 3. The population is further divided between households that provide production labour and those providing professional

[10] Canada has a GDP^{PPP} to GDP^{MER} ratio of 1.2 and accounts for 8% of the North American PPP multiplier. The United States has a GDP^{PPP} to GDP^{MER} ratio of approximately 1, as can be expected since all data is listed of US currency, and accounts for 83% of the PPP multiplier.

[11] See also Shi and Tyers (2004) and Tyers et al. (2005).

[12] The *GTAP-Dynamic* model is a development of its comparative static progenitor, *GTAP* (Hertel et al. 1997). Its dynamics is described by Ianchovichina and McDougall (2000). Earlier applications of the standard model to the issues raised in this paper include those by Shi and Tyers (2004) and Duncan, Shi and Tyers (2005).

[13] The demographic sub-model has been used in stand alone mode for the analysis of trends in dependency ratios. For a more complete documentation of the sub-model, see Chan and Tyers (2006).

labour.[14] Each age-gender-skill group is a homogeneous sub-population with group-specific birth and death rates and rates of both immigration and emigration.[15] If the group spans T years, the survival rate to the next age group is the fraction $1/T$ of its population, after group-specific deaths have been removed and its population has been adjusted for net migration.

The final age group (60+) has duration equal to measured life expectancy at 60, which varies across genders and regions. The key demographic parameters, then, are birth rates, sex ratios at birth, age and gender specific death, immigration and emigration rates and life expectancies at 60.[16] Immigration rates are a particular focus here and these are responsive to inter-regional real wage comparisons, constrained in a manner designed to represent the impacts of immigration policy. A further key parameter is the rate at which each region's education and social development structure transforms production worker families into professional worker families. Each year a particular proportion of the population in each production worker age-gender group is transferred to professional status. These proportions have an exogenous component that is set depending on the regions' levels of development, the associated capacities of their education systems and the relative sizes of the production and professional labour groups. They are also responsive to regional skilled wage premia, to an extent that is readily adjusted to reflect changes in the capacities of education and training systems.

In any year, for each age group, a, gender group g, skill group s, region of origin, r and region of destination, d, the volume of migration flow is:

$$(5) \qquad M^{t}_{a,g,s,r,d} = \delta^{t}_{d} M^{R}_{a,g,s,r,d} N^{t}_{a,g,s,d}, \quad \forall a,g,r,d \ ,$$

where δ^{t}_{d} is a destination-specific factor reflecting immigration policy in region d, set to unity in all but counterfactual experiments, M^{R}_{agsrd} is the migration rate between r and d expressed as a proportion of the group population in region d, N_{agsd}. The migration rate is then responsive to regional differences in real wages via:

$$(6) \qquad M^{R}_{a,g,s,r,d} = M^{R0}_{a,g,s,r,d} \left[\left(\frac{W_{s,d}}{P^{C}_{d}} \right) \Big/ \left(\frac{W_{s,r}}{P^{C}_{r}} \right) \right]^{\varepsilon^{M}_{a,g,s,r,d}} ,$$

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[14] The subdivision between production and professional labour accords with the ILO's occupation-based classification and is consistent with the labour division adopted in the GTAP Database. See Liu et al. (1998).

[15] Mothers in families providing production labour are assumed to produce children that will grow up to also provide production labour, while the children of mothers in professional families are correspondingly assumed to become professional workers.

[16] Immigration and emigration are also age and gender specific. The model represents a full matrix of global migration flows for each age and gender group. Each of these flows is currently set at a constant proportion of the population of its destination group. See Chan and Tyers (2006) and Vedi (2005) for further details.

where $W_{s,r}$ and $W_{s,d}$ are wage rates by skill level in regions of origin and destination (measured relative to a common global numeraire), P_r^C and P_d^C are consumer price levels in the two regions (measured relative to the same global numeraire) and $\varepsilon^M_{a,g,s,r,d}$ is an elasticity of response that reflects the extent to which immigration policies constrain the bilateral flow between *r* and *d*.

Given the migration matrix, M_{agsrd}, the population in each age, gender and skill group and region can be constructed. We begin with the population of males aged 0-14 from professional families in region *d* (*a=014, g=m, s=sk, r=d*).

$$\begin{aligned} N^t_{014,m,sk,d} &= N^{t-1}_{014,m,sk,d} + \frac{S^t_d}{1+S^t_d} B^t_{sk,d} N^{t-1}_{1539,f,sk,d} \\ &\quad - D^t_{014,m,sk,d} N^{t-1}_{014,m,sk,d} + \sum_r M^t_{014,m,sk,r,d} - \sum_r M^t_{014,m,sk,d,r} \\ &\quad + \rho_d N^{t-1}_{014,m,unsk,d} - \frac{1}{15}\left[N^{t-1}_{014,m,sk,d} - D^t_{014,m,sk,d} N^{t-1}_{014,m,sk,d}\right], \quad \forall d \end{aligned} \tag{7}$$

where S^t_d is the sex ratio at birth (the ratio of male to female births) in region *d*, $B^t_{s,d}$ is the birth rate for women of skill level *sk*, $D^t_{014,m,d}$ the death rate and ρ_d is the rate at which region *d*'s educational institutions and general development transform production into professional worker families. The final term is survival to the corresponding 15-39 age group. In the corresponding equation for young males from production worker families the penultimate term is negative and the subscript *sk* is replaced with *unsk* in all but that penultimate term.

For females in professional families in this age group the corresponding equation is:

$$\begin{aligned} N^t_{014,f,sk,d} &= N^{t-1}_{014,f,sk,d} + \frac{1}{1+S^t_d} B^t_{sk,d} N^{t-1}_{1539,f,sk,d} \\ &\quad - D^t_{014,f,sk,d} N^{t-1}_{014,f,sk,d} + \sum_r M^t_{014,f,sk,r,d} - \sum_r M^t_{014,f,sk,d,r} \\ &\quad + \rho_d N^{t-1}_{014,f,unsk,d} - \frac{1}{15}\left[N^{t-1}_{014,f,sk,d} - D^t_{014,f,sk,d} N^{t-1}_{014,f,sk,d}\right], \quad \forall d \end{aligned} \tag{8}$$

For adults of gender *g* from professional families in the age group 15-39 the equation includes a survival term from the younger age group. It is:

$$\begin{aligned} N^t_{1539,g,sk,d} &= N^{t-1}_{1539,g,sk,d} + \frac{1}{15}\left[N^{t-1}_{014,g,sk,d} - D^t_{014,g,sk,d} N^{t-1}_{014,g,sk,d}\right] \\ &\quad - D^t_{1539,g,sk,d} N^{t-1}_{1539,g,sk,d} + \sum_r M^t_{1539,g,sk,r,d} - \sum_r M^t_{1539,g,sk,d,r} \\ &\quad + \rho_d N^{t-1}_{1539,g,unsk,d} - \frac{1}{25}\left[N^{t-1}_{1539,g,sk,d} - D^t_{1539,g,sk,d} N^{t-1}_{1539,g,sk,d}\right], \quad \forall g,d \end{aligned} \tag{9}$$

where the second term is the surviving inflow from the 0-14 age group and the final term is the surviving outflow to the 40-59 age group. Again, the skill transformation term is negative in the case of the corresponding equation for production worker families. The population of professional adults of gender *g*, in age group 40-59 follows as:

$$\begin{aligned} N^t_{4059,g,sk,d} &= N^{t-1}_{4059,g,sk,d} + \frac{1}{25}\left[N^{t-1}_{1539,g,sk,d} - D^t_{1539,g,sk,d} N^{t-1}_{1539,g,sk,d}\right] \\ &\quad - D^t_{4059,g,sk,d} N^{t-1}_{4059,g,sk,d} + \sum\nolimits_r M^t_{4059,g,sk,r,d} - \sum\nolimits_r M^t_{4059,g,sk,d,r} \\ &\quad + \rho_d N^{t-1}_{4059,g,unsk,d} - \frac{1}{20}\left[N^{t-1}_{4059,g,sk,d} - D^t_{4059,g,sk,d} N^{t-1}_{4059,g,sk,d}\right], \quad \forall g,d \end{aligned} \tag{10}$$

For adults in the 60+ age group, the corresponding relationship is:

$$\begin{aligned} N^t_{60+,g,sk,d} &= N^{t-1}_{60+,g,sk,d} + \frac{1}{20}\left[N^{t-1}_{4059,g,sk,d} - D^t_{4059,g,sk,d} N^{t-1}_{4059,g,sk,d}\right] \\ &\quad + \sum\nolimits_r M^t_{60+,g,sk,r,d} - \sum\nolimits_r M^t_{60+,g,sk,d,r} \\ &\quad + \rho_d N^{t-1}_{60+,g,unsk,d} - \frac{1}{L^t_{60+,g,sk,d}} N^{t-1}_{60+,g,sk,d}, \quad \forall g,d \end{aligned} \tag{11}$$

where the final term indicates that deaths from this group each year depend on its life expectancy at 60, $L^t_{60+,g,sk,d}$. Again, the equation for aged production worker family members is the same except that the skill transformation term is negative.

Finally, ρ_d, the rate at which region *d*'s educational institutions and general development transform production into professional worker families depends on the level of the region's real GNP per capita and on the size of its skilled wage premium.

$$\rho_d = \rho^0_d \left(\frac{W_{sk,d}}{W_{unsk,d}}\right)^{\varepsilon^{TW}_d}, \text{ where } \varepsilon^{TW}_d = \varepsilon^{TW0}_d \left(\frac{GNP_d}{N_d P^C_d} \bigg/ \frac{GNP^0_d}{N^0_d P^{C0}_d}\right)^{\varepsilon^{TY}_d}. \tag{12}$$

ε^{TW}_d is the elasticity of the transformation rate to the skilled to unskilled wage ratio. This elasticity is thought to be larger the more developed the region. To represent this, it is set to grow with real per capita GNP according to elasticity ε^{TY}_d.

Sources and structure:

Key parameters in the model are the migration rates, $M^R_{a,g,s,r,d}$, birth rates, $B^t_{s,r}$, sex ratios at birth, S^t_r, death rates, $D^t_{a,g,s,r}$, life expectancies at 60, $L^t_{60+,g,s,r}$ and the skill transformation rates ρ_d. The migration *rates* are based on the flows analysed in Section 2. In the base line projection they are held constant through time – the elasticity $\varepsilon^M_{a,g,s,r,d}$ is made negligibly small. The skill transformation rates are based on changes during the decade prior to the base year, 1997, in the composition of aggregate regional labour forces as between production and professional workers. In the base line projection these are also held constant through time – the elasticities ε_d^{TW} and ε_d^{TY} are made negligibly small.[17]

Asymptotic trends in other parameters:

The birth rates, life expectancy at 60 and the age specific mortality rates all trend through time asymptotically. For each age group, *a*, gender group, *g*, and region, *r*, a target rate is identified.[18] The parameters then approach these target rates with initial growth rates determined by historical observation. In year *t* the birth rate of region *r* is:

(13) $$B_r^t = B_r^0 + \left(B_{Tgt}^0 - B_r^0\right)\left(1 - e^{\beta t}\right) ,$$

where the rate of approach, *β*, is calibrated from the historical growth rate:

(14) $$\hat{B}_r^0 = \frac{B_r^1 - B_r^0}{B_r^0} = \frac{\left(B_{Tgt}^0 - B_r^0\right)\left(1 - e^{\beta}\right)}{B_r^0}, \text{ so that}$$

(15) $$\beta = \ln\left[1 - \frac{B_r^0 \hat{B}_r^0}{B_{Tgt}^0 - B_r^0}\right] .$$

Labour force projections:

To evaluate the number of "full-time equivalent" workers we first construct labour force participation rates, $P_{a,g,r}$ by gender and age group for each region from ILO statistics on the "economically active population". We then investigate the proportion of workers that are part time and the hours they work relative to each regional standard for full time work. The result is the number of full time equivalents per worker, $F_{a,g,r}$. The labour force in region *r* is then:

(16) $$\bar{L}_r^t = \sum_{a=1539}^{60+} \sum_{g=m}^{f} \sum_{s=sk}^{unsk} L_{a,g,s,r}^t \text{ where } L_{a,g,s,r}^t = \mu_{a,r}^t P_{a,g,r}^t F_{a,g,r} N_{a,g,s,r}^t .$$

Here $\mu_{a,r}^t$ is a shift parameter reflecting the influence of policy on participation rates. The time superscript on $P_{a,g,r}^t$ refers to the extrapolation of observed trends in these parameters.[19]

Asymptotic trends in labour force participation:

[17] Note that, as regions become more advanced and populations in the production worker families become comparatively small, the skill transformation rate has a diminishing effect on the professional population.
[18] In this discussion the skill index, s, is omitted because birth and death rates, and life expectancies at 60 do not vary by skill category in the version of the model used.
[19] Although part time hours may well also be trending through time, we hold *F* constant in the current version of the model.

For each age group, a, gender group, g, and region, r, a target country is identified whose participation rate is approached asymptotically. The rate of this approach is determined by the initial rate of change. Thus, the participation rate takes the form:

$$(17) \qquad P^t_{a,g,r} = P^0_{a,g,r} + \left(P^0_{Tgt} - P^0_{a,g,r}\right)\left(1 - e^{\beta t}\right) \ ,$$

where the rate of approach, β, is calibrated from the initial participation growth rate:

$$(18) \qquad \hat{P}^0_{a,g,r} = \frac{P^1_{a,g,r} - P^0_{a,g,r}}{P^0_{a,g,r}} = \frac{\left(P^0_{Tgt} - P^0_{a,g,r}\right)\left(1 - e^{\beta}\right)}{P^0_{a,g,r}}, \text{ so that}$$

$$(19) \qquad \beta = \ln\left[1 - \frac{P^0_{a,g,r}\hat{P}^0_{a,g,r}}{P^0_{Tgt} - P^0_{a,g,r}}\right].$$

Target rates are chosen from countries considered "advanced" in terms of trends in participation rates. Where female participation rates are rising, therefore, Norway provides a commonly chosen target because its female labour force participation rates are higher than for other countries.[20]

Accounting for part time work:

For each age group, a, gender, g, and region, r, full-time equivalency depends on the fraction of participants working full time, $f_{a,g,r}$, and, for those working part time, the ratio of average part time hours to full time hours for that gender group and region, $r_{g,r}$. For each group, the ratio of full time equivalent workers to total labour force participants is then

$$(20) \qquad F_{a,g,r} = f_{a,g,r} + \left(1 - f_{a,g,r}\right) r_{g,r} .$$ [21]

The aged dependency ratio:

We define and calculate four dependency ratios: 1) a youth dependency ratio is the number of children per full time equivalent worker, 2) an aged dependency ratio is the number of persons over 60 per full time equivalent worker, 3) a non-working aged dependency ratio is the number of non-working persons over 60 per full time equivalent worker, and 4) a more general dependency ratio is defined that takes as its numerator the total non-working population, including children.[22] That of used here is the one of most widespread policy interest, the non-working aged dependency ratio:

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[20] The resulting participation rates are listed by Chan and Tyers (2005: Table 10).

[21] Preliminary estimates of $f_{a,g,r}$ and $r_{g,r}$ are approximated from OECD (1999: Table 1.A.4) and OECD (2002: Statistical Annex, Table F). No data has yet been sought on part time work in non-OECD member countries. In these cases the diversity of OECD estimates is used to draw parallels between countries and regions and thus to make educated guesses. The results are listed by Chan and Tyers (2006: Tables 11 and 12).

[22] All these dependency ratios are defined in detail by Chan and Tyers (2006).

$$(21) \qquad R_{r,t}^{ANW} = \frac{\sum_{g=m}^{f} \sum_{s=sk}^{unsk} \left(N_{60+,g,sk,r}^{t} - L_{60+,g,sk,r}^{t} \right)}{\bar{L}_{r}^{t}} \; .$$

4.2 The Global Economic Model

GTAP-Dynamic is a multi-region, multi-product dynamic simulation model of the world economy. It is a microeconomic model, in that assets and money are not represented and prices are set relative to a global numeraire. In the version used, the world is subdivided into 14 regions. Industries are aggregated into just three sectors, food (including processed foods), industry (mining and manufacturing) and services. To reflect composition differences between regions, these products are differentiated by region of origin, meaning that the "food" produced in one region is not the same as that produced in others. Consumers substitute imperfectly between foods from different regions.

As in most other dynamic models of the global economy, in *GTAP-Dynamic* the endogenous component of simulated economic growth is physical capital accumulation. Technical change is introduced in the form of exogenous trends and skill (or human capital) acquisition is driven by the constant transformation rates introduced in the previous section. A consequence of this is that the model exhibits the property of all dynamic models of the Solow-Swan type that incorporate diminishing returns to factor use, namely that an increase in the growth rate of the population raises the growth rate of real GDP but reduces the level of real per capita income. What distinguishes the model from this simpler progenitor is its recursive multi-regional dynamics. Investors have adaptive expectations about the real net rates of return on installed capital in each region. These drive the distribution of investment across regions. In each, the level of investment is determined by a comparison of net rates of return with borrowing rates yielded by a global trust to which each region's saving contributes.

To capture the full effects of demographic change, including those of ageing, the standard model has been modified to include multiple age, gender and skill groups in line with the structure of the demographic sub-model. In the complete model, these 16 groups differ in their consumption preferences, saving rates and their labour supply behaviour. Unlike the standard *GTAP* models, in which regional incomes are split between private consumption, government consumption and total saving via an upper level Cobb-Douglas utility function that implies fixed regional saving rates, this adaptation first divides regional incomes between government consumption and total private disposable income. The implicit assumption is that governments balance their budgets while private groups save or borrow.

In splitting each region's private disposable income between the eight age-gender groups, the approach is to construct a weighted subdivision that draws on empirical studies of the distribution of disposable income between age-gender groups for "typical" advanced and developing countries.[23] Individuals in each age-gender group then split their disposable incomes between consumption and saving. For this a reduced form approach is taken to the intertemporal optimisation problem faced by each. It employs an exponential consumption equation that links group real per capita consumption expenditure to real per capita disposable income and the real interest rate. This equation is calibrated for each group and region based on a set of initial (1997) age-specific saving rates from per capita disposable income.[24] Importantly, these show transitions to negative saving with retirement in the older industrial regions. This gives rise to declines in average saving rates as population's age. The empirical studies on age-specific saving behaviour are less clear, however, when it comes to developing regions. In the important case of China, for example, only modest declines in saving rates are recorded when people retire. This is partly due to the complication that a comparatively large proportion of consumption spending by the Chinese elderly, and those in other developing regions, is financed from the income of younger family members.

5. Constructing the Base Line Scenario

The base line scenario represents a "business as usual" projection of the global economy through 2030. Although policy analysis can be sensitive to the content of this scenario, the focus of this paper is on the extent of departures from it that would be caused by alternative levels of responsiveness of migration flows to inter-regional real wage divergences. Nonetheless, it is instructive to describe the base line, because all scenarios examined have in common a set of assumptions about future trends in productivity and because some exposition of the base line makes the construction of departures from it clearer.

Exogenous factor productivity growth

Exogenous sources of growth enter the model as factor productivity growth shocks, applied separately for each of the model's five factors of production (land, physical capital, natural resources, production labour and professional labour). Simulated growth rates are very sensitive to productivity growth rates since, the larger these are for a particular region the larger is that region's marginal product of capital. The region therefore enjoys higher levels of investment and hence a double boost to its per capita real income growth rate. The

[23] The analytics of income splitting are described in detail by Tyers et al. (2005).
[24] For further details, see Tyers et al. (2005).

importance of productivity notwithstanding, the empirical literature is inconsistent as to whether productivity growth has been faster in agriculture or in manufacturing and whether the gains in any sector have enhanced all primary factors or merely production labour. The factor productivity growth rates assumed in all scenarios are drawn from a new survey of the relevant empirical literature (Tyers et al. 2005). Agricultural productivity grows more rapidly than that in the other sectors in China, along with Australia, Indonesia, Other East Asia, India and Other South Asia. This allows continued shedding of labour to the other sectors. In the other industrialised regions, the process of labour relocation has slowed down and labour productivity growth is slower in agriculture. In the other developing regions, the relocation of workers from agriculture has tended not to be so rapid.

Interest premia

The standard *GTAP-Dynamic* model takes no explicit account of financial market maturity or investment risk and so tends to allocate investment to regions that have high marginal products of physical capital. These tend to be labour-abundant developing countries whose labour forces are still expanding rapidly. Although the raw model finds these regions attractive prospects for this reason, we know that considerations of financial market segmentation, financial depth and risk limit the flow of foreign investment at present and that these are likely to remain important in the future. To account for this we have constructed a "pre-base line" simulation in which we maintain the relative growth rates of investment across regions. In this simulation, global investment rises and falls but its allocation between regions is thus controlled.

To do this the interest premium variable (*GTAP Dynamic* variable *SDRORT*) is made endogenous. This creates wedges between the international and regional borrowing rates. They show high interest premia for the populous developing regions of Indonesia, India, South America and Sub-Saharan Africa. Premia tend to fall over time in other regions, where labour forces are falling or growing more slowly. Most spectacular is a secular fall in the Chinese premium. This is because the pre-base simulation maintains investment growth in China despite an eventual decline in its labour force. This simulation is therefore overly optimistic with respect to China and so we reject the drastic declines in the investment premium that it implies. In constructing the final base line scenario, we allow a fall in China's premium by 1.5 percentage points.[25] The time paths of all interest premia are set as

[25] See Tyers and Golley (2006) for further details on the treatment of China.

exogenous and regional investment is freed up in all regions. Investment is then retained as endogenous in the model's closure in all subsequent simulations.

The base line projection

Demographic changes in the base line projection are characterised by declining fertility and ageing everywhere. The key demographic differences between regions concern their initial age distributions – the industrialised regions begin with older populations than the developing ones and so, generally, population growth continues to be higher in the developing regions, and particularly in South Asia and Africa, as shown in Figure 4. The pervasive ageing is suggested by the projected sizes and composition of regional labour forces in Table 4 and the non-working aged dependency ratios in Table 5. The corresponding base line projection for the global economy is suggested by Table 6, which details the average GDP and real per capita income growth performance of each region from 1997 to 2030. In part because of its comparatively young population and hence its continuing rapid labour force growth, India attracts substantial new investment and is projected to take over from China as the world's most rapidly expanding region. Rapid population growth detracts from India's real per capita income performance, however. By this criterion, China is the strongest performing region through the three decades. Indonesia and "other East Asia" are also strong performers, while the older industrial economies continue to grow more slowly. The African regions enjoy good GDP growth performance but their high population growth rates limit their performance in per capita terms.

6. Increasing Responsiveness to Real Wage Divergences

The shocks introduced centre on the elasticities in equations (6) and (12). Recall from (6) that $\varepsilon^{M}_{a,g,s,r,d}$ is the elasticity of the migration rate for skill level *s* between regions *r* and *d* to the ratio of the destination and origin real wages. In the base line simulation, this elasticity is set to negligibility, so that migration flows are driven only by the sizes of destination populations in each age-gender group. That is, flows maintain base period rates of migration over destination populations in each bilateral direction for each age-gender group. The first alternative simulation, labelled ***M1***, simply expands this elasticity, for skilled workers only, to a value of 0.5 in the interval 2000-2010. Skilled migration flows then increase by most between low and high real wage regions. Because this additional migration makes skilled workers scarcer in the regions of origin, however, the skill premium rises in those regions.

This might be expected to induce a skill-acquisition response from production workers in the regions of origin.

Allowance for accelerated skill transformation takes the form of (12), in which ε_d^{TW} is the elasticity of the transformation rate to ratio of skilled and production real wages and ε_d^{TY} governs the response of ε_d^{TW} to rising real per capita incomes and hence rising educational opportunity. A second alternative simulation is constructed that is the same as ***M1*** except that accelerated skill transformation is allowed by adjusting these elasticities. More particularly, the new simulation, labelled ***M2***, has ε_d^{TY} rising to a value of 0.218.[26] Since ε_d^{TW} is set at negligibility in the base line, so that skill transformation rates are constant for each region, its enlargement enables responses to pre-existing skill premia. Where these are large, as is most notably the case in Sub-Saharan Africa (Figure 2), skill acquisition can therefore be expected to accelerate most. The values attained for the transformation rates are listed in Table 7.

Expanding migration in a manner that is responsive to real wage differences is found, not surprisingly, to yield "more of the same" in terms of the direction of migration flows. This is clear from comparing the patterns of base period annual flows, indicated in Figure 1, with the accumulated flows over the next three decades shown in Figure 5. Except in the cases of two prominent regions of origin, Central Europe and the former Soviet Union and the "rest of the world" group, migrants tend to leave populous regions, so that their departures have little effect on most populations of regions of origin. They do make a significant difference in the principal regions of destination, however, Western Europe, North America and Australia, as shown in Figure 6.[27] Of the regions identified, the skilled migrant intake is largest relative to the destination population in Australia, where the additional migrants expand the 2030 population by almost a tenth.

The economic effects of these migrant flows come from changes in skilled labour forces and, because the migrants tend to be younger than the average age in destination regions, changes in non-working aged dependency ratios. The labour force effects are suggested by Figure 7 and detailed in Table 8. The skilled labour forces of Western Europe, North America and Australia are raised by between a tenth and a quarter, while those of the key regions of origin fall. The corresponding effects on aged dependency are smaller, however. Considering the large three-decade increases in the base line (Table 5), the 2030 non-working aged dependency ratios of the principal destination regions fall only by a

[26] Higher values cause the skill premia in some regions to collapse.
[27] The Middle East and North Africa is also a prominent destination region, particularly for workers from South and Southeast Asia, but this migration remains small in relation to the population of that region.

fraction of a per cent in Western Europe, a percent or so in North America and nearly two per cent in Australia (Table 9). Clearly, the age distribution effects are modest and expanded migration is unlikely to be a solution to the fiscal problems associated with ageing.[28]

The expanded skilled labour forces in the principal destination regions do have economic implications, however. Although their effects on the average growth rates of GDP over three decades are small compared with the drivers of base line growth (Figure 8), the overall economies of the destination regions are larger than their base line levels by between two and eight per cent (Figure 9). When the additional effect of skill acquisition is added, in ***M2***, there are further boosts to GDP in the destination regions (Figure 10). This time, however, the change in skill composition in some regions of origin outweighs the effect of emigration and so also raises their GDP levels. For the world as a whole, the migrations raise 2030 global GDP by 1.6 per cent. The assumed homogeneity of professional workers across regions and the market exchange rate database of the *GTAP-Dynamic* model, which tends to make labour productivity in tradeable goods sectors more similar than the actual wage data of Section 3 suggest, both act to reduce the estimated global GDP gains from the relocation of skilled workers.

The impacts of increased migration on labour markets are shown in Figure 11. They are straight-forward. In ***M1***, where there is no change in the rate of skill acquisition within regions, real skilled wages fall in destination regions, which experience increased skilled labour supply, and rise in regions of origin. Production wages rise in the destination regions, since the rise in the supply of skill raises the marginal product of production labour there. The opposite is true in regions of origin, where the skill supply falls. It is also evident from Figure 11 that the skill premium falls in the destination regions and rises in the regions of origin. Even though the labour forces of India and "other South Asia" are very large by comparison with their emigrations, their skilled labour forces are reduced by measurable proportions (Figure 7). This causes the significant increases in their skilled wage rates relative to the base line projection, shown in Figure 11 and listed in Table 10. The corresponding changes in East and Southeast Asia are smaller because skilled wages are higher there at the outset and so proportionally smaller emigrations are induced.[29]

It is the widening of skill premia in the regions of origin that suggest the possibility that higher rates of skill acquisition might be induced in these regions. When these are allowed for, in ***M2***, the general pattern of wage changes in the destination regions is not

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[28] This is a well-established conclusion in demography that has been re-examined following the rise in concern about ageing and slower growth in Europe. See, for example, Young (1990) and United Nations (2000a).

[29] The pattern for the "Middle East and North Africa" is reversed, of course, because this region is a destination for migrants due to its concentrations of petroleum wealth, even though it includes many poor countries.

greatly different. Their skill premia contract by more because additional skill acquisition is stimulated through its increased sensitivity to their existing skill premia. This is most pronounced in North America, where the skill premium is larger at the outset than it is either in Western Europe or Australia (Figure 2).

In the regions of origin the rates of skill acquisition expand more markedly. Not only is this due to the loss of skilled workers abroad and the resultant widening of their skill premia, but, as Figure 11 also shows, the most pronounced effects are in the poorest regions, where the base period skill premia were extremely high (Figure 2). For this reason, the wage of skilled workers falls by most in the Middle East and North Africa and in Sub-Saharan Africa. It falls by more modest yet significant proportions in South America and in East and Southeast Asia, where this constitutes a reversal of the effects of pure skilled migration (***M1***). That reversal is due to the dominance over skilled wage determination by the domestic skill transformation process, with its enhanced sensitivity to high domestic skill premia, rather than by emigration.

Returning to the declines in skill premia in the principal destination regions, the extent of this is, understandably, quite sensitive to the real wage divergence elasticity, $\varepsilon^{M}_{a,g,s,r,d}$. To minimise arbitrariness, we have shocked this elasticity to the same level (0.5) on all bilateral migration links. Too large an increase in this elasticity (say to a value of unity) causes the collapse of skill premia, first in Australia, where the proportional effects of the migrations are largest. The scale of the wage convergence embodied in the results shown in Figure 11 is further elucidated in Figures 12 through 14. In Australia, the skill premium is reduced in proportion, though not in level, while in North America and Western Europe, it is merely stabilised in proportion. Convergence of wage rates between regions, however, remains very modest, even with this substantial increase in skill migration flows (Table 10). All this suggests that global labour markets offer scope for still further expansions in skilled migration.

Finally, the net effects of all this on real per capita income are indicated in Table 11. They are surprisingly small, each a fraction of a per cent of 2030 real per capita income. The migration-only effects, from ***M1***, are two-fold. First, immigration raises the domestic population, always decreasing real income per capita in this neoclassical framework.[30] Second, the skill-composition of the labour force is increased by the immigration, which tends

[30] This result is common to all models where the growth rate depends on the rate of physical capital accumulation and where there are diminishing returns to capital and labour, the simplest of these models being that of Solow (….) and Swan (….). While our model has exogenous technical change it occurs at constant rates, which are independent of capital accumulation and common to the base line, ***M1*** and ***M2*** simulations.

to raise real income per capita and hence at least partially offset the population effect. In Australia, because of the dominance of the population-expanding effect, real per capita income is shown to decline. In North America and Western Europe, however, the effects on their total populations are smaller relative to those of their skill distributions and so the net effect on their per capita incomes is positive. Moreover, in these large regions the immigrations affect the terms of trade. Both are net importers of labour-intensive goods and, while each is large in economic terms, their labour forces are substantially smaller than those of the sum of their trading partners. This means that, drawing labour from their trading partners causes proportional increases in their labour forces that are larger than the complementary proportional decreases in the labour forces of other regions. The migrations therefore improve their terms of trade by reducing their excess demand for labour intensive goods to an extent that is proportionally larger than the reduction in their collective trading partners' excess supplies. Finally, when changed rates of skill-acquisition are added in ***M2***, there are gains in real per capita income in all regions, relative to ***M1***. Again, this is because the proportion of workers in the higher-earning skilled category has risen. Not surprisingly, these extra gains are largest in the Middle East and in Africa.

7 Conclusion

To investigate the effects on labour markets and the distribution of growth, a new demographic sub-model that is integrated with an adaptation of the *GTAP-Dynamic* global economic model. Skilled migration flows are assumed to be motivated by real wage differences to an extent that is variably constrained by immigration policies. A uniform relaxation of these constraints on all inter-regional migration flows has most effect on labour markets in the traditional migration destinations, Australia, Western Europe and North America, where it restrains the skill premium and substantially enhances GDP growth. The skill premium is raised, however, in regions of origin, and particularly in South Asia, although the extent of this is shown to depend sensitively on the assumed responsiveness of skill acquisition to regional skill premia. In regions where skill premia are high at the outset, such as in North America, the Middle East and Africa, skill acquisition then has a larger effect on regional wages than does migration.

The effects of expanded skilled migration on real per capita incomes depend on its implications for population sizes, labour force skill shares and the international terms of trade. As it turns out, these different effects tend to be off-setting, so that net changes in real per capita incomes are proportionally small.

Four important caveats must be borne in mind. First, our base period matrices of migration flows leave room for improvement, since, given the paucity of standardised migration data, their construction depends on numerous assumptions. New research on the documentation of migration stocks and flows will soon render some of those assumptions unnecessary. Second, because our flow matrices are constructed from corresponding matrices of migrant stocks that are based originally on census data, there is no distinction between short- and long-stay migrants and hence no accounting for remittance payments. Third, our model depends heavily on the GTAP global database, which takes incomplete account of inter-regional variations in the pricing of goods and services that are costly to trade. Indeed, in the standard version of the model the levels of wages and of factor endowments do not need to be made explicit. This means that inter-regional differences in factor productivity are imperfectly accounted for and PPP adjustments are needed in modelling the motive for migration. We have blended the standard database with additional information about labour supplies and wage levels to make possible our analysis of increases in the responsiveness of migration flows to wage divergences. In the long run, a more systemic solution to this problem is required, since solutions to this problem are required not only for applications of such models to migration but also to energy and environmental issues. Finally, although there is evidence to support it, we do not allow the fertility of professional households to depart from that of production worker households. Since a perception that skilled households have reduced fertility is an important aspect of the motivation for skill shortage claims in the industrial countries, further research on the topic should better account for variations not only in fertility but also in other demographic parameters by the professional status of households.

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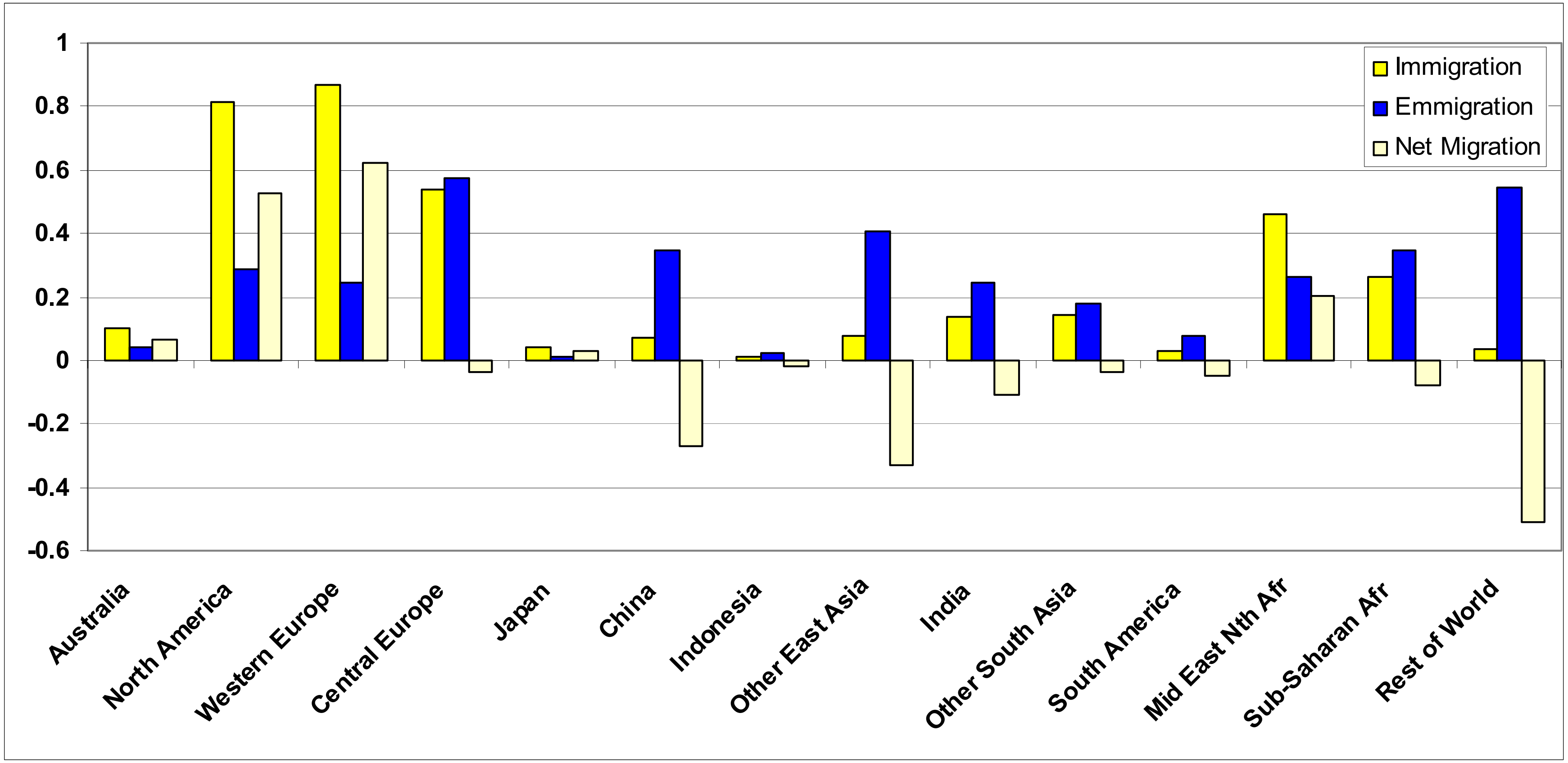


Figure 1: Annual migration flows: immigration, emigration and net migration

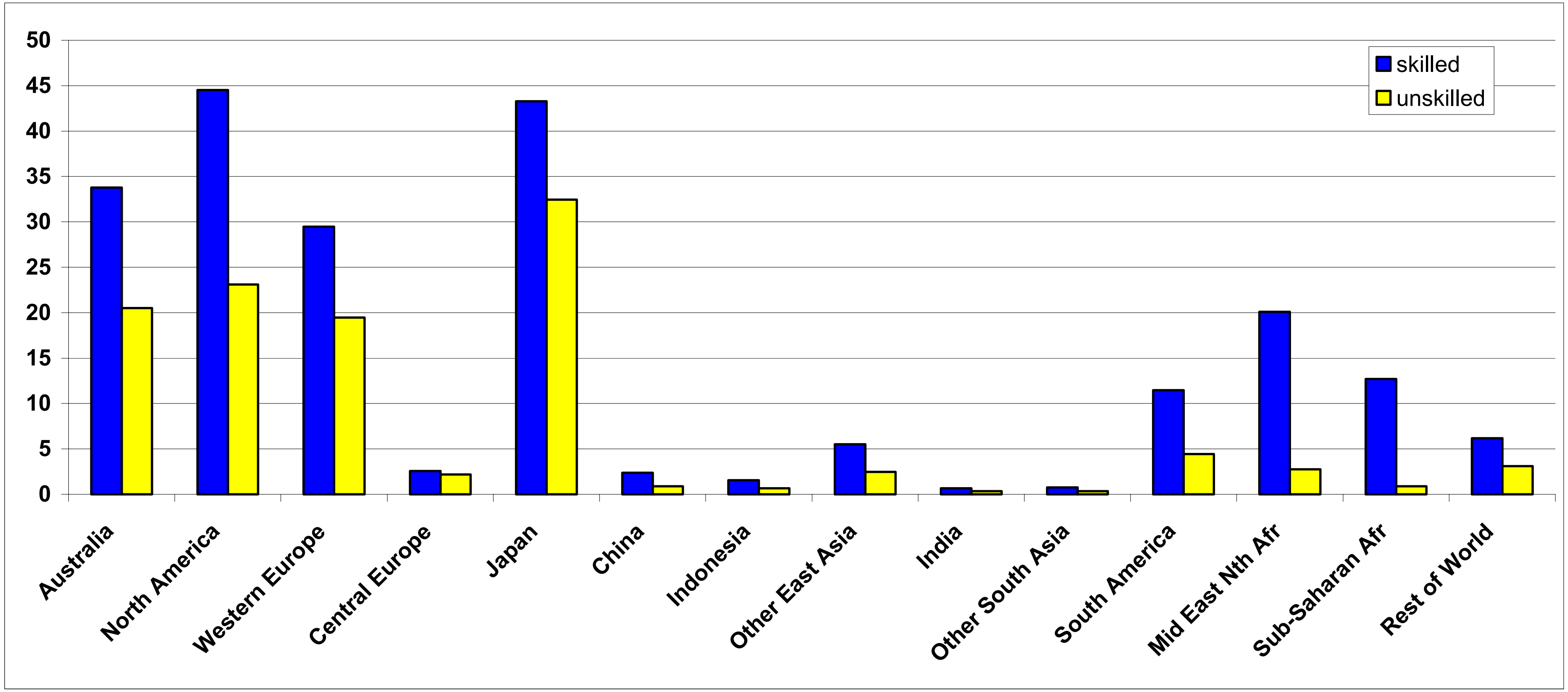
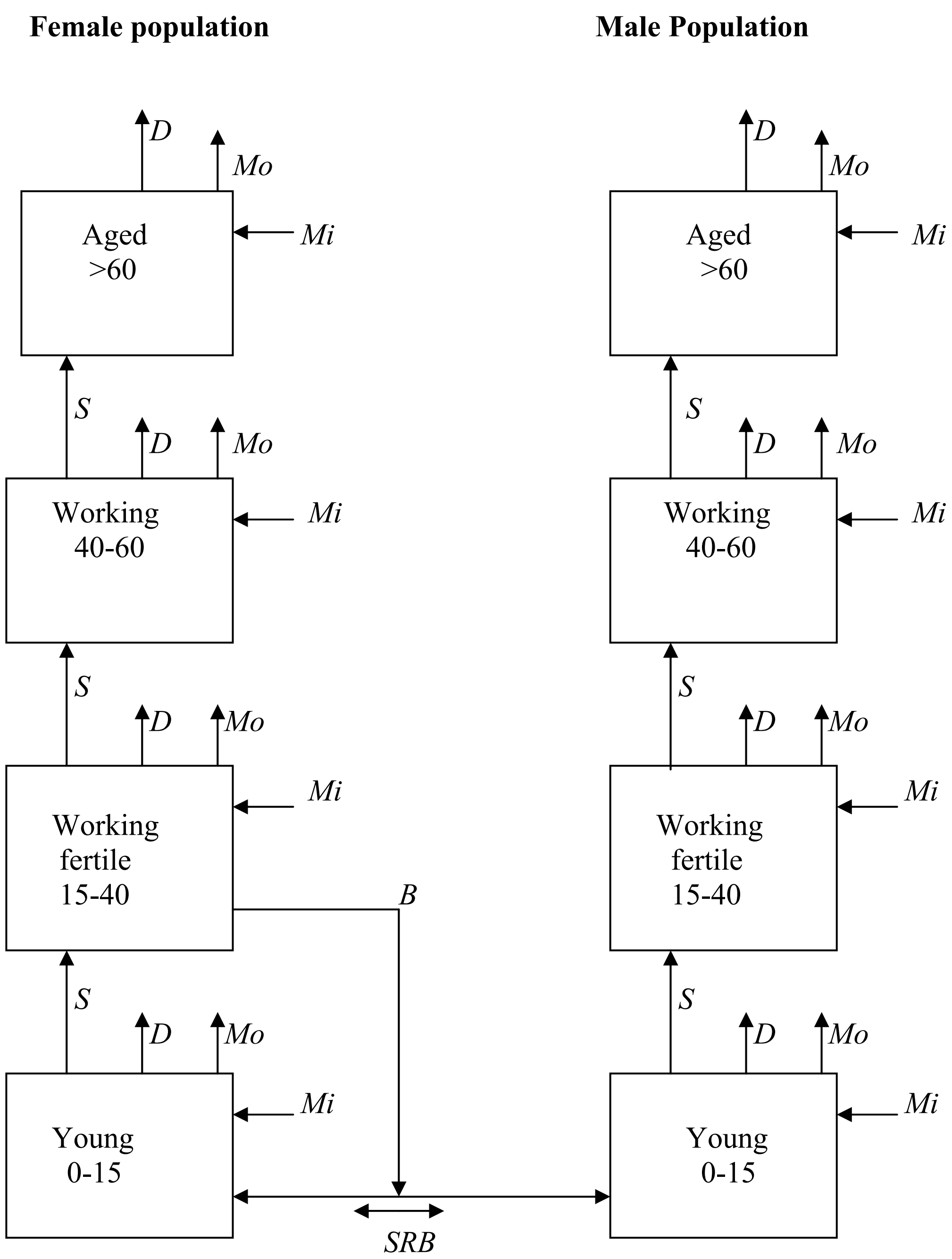


Figure 2: Initial Wages per Worker in each Region by Skill Level
$US '000

Figure 3: The Demographic Sub-Model



Glossary:

D	Deaths
S	Survival
B	Births
Mi	Immigration
Mo	Emigration
SRB	Sex ratio at birth

Figure 4: Base Line Changes in Global Population Distribution

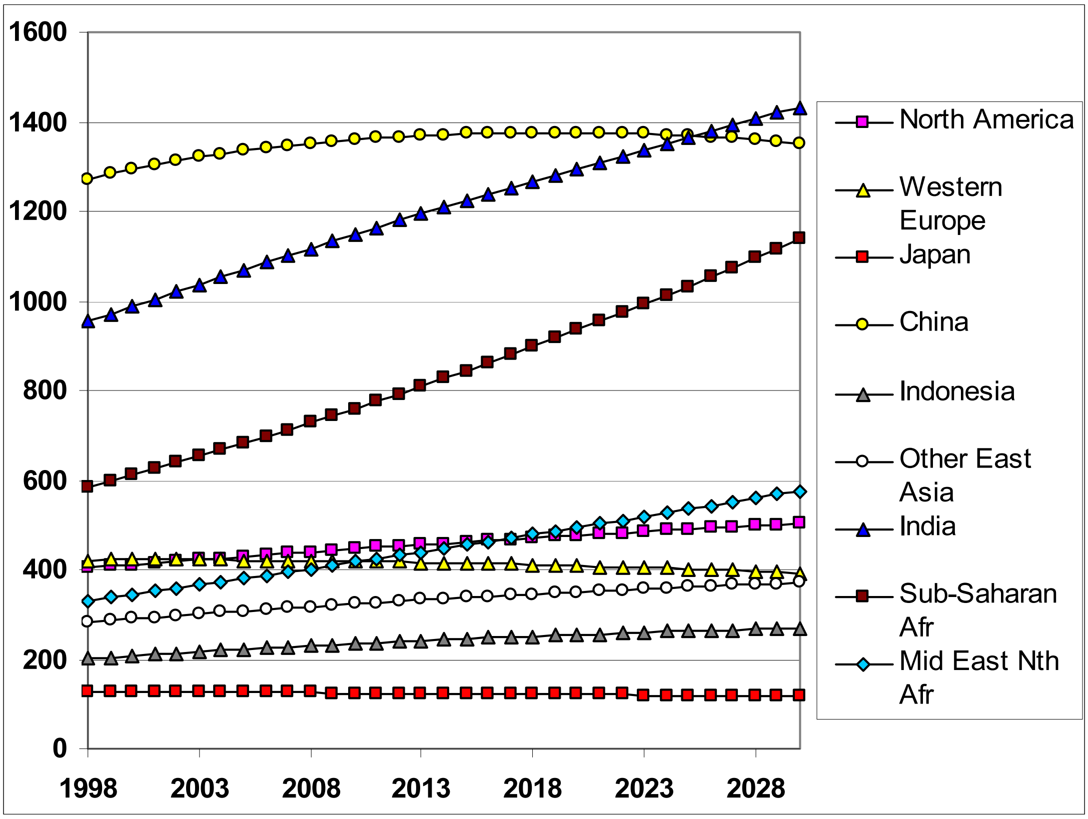


Figure 5: Net Migration Movement, 1997-2030, in Millions

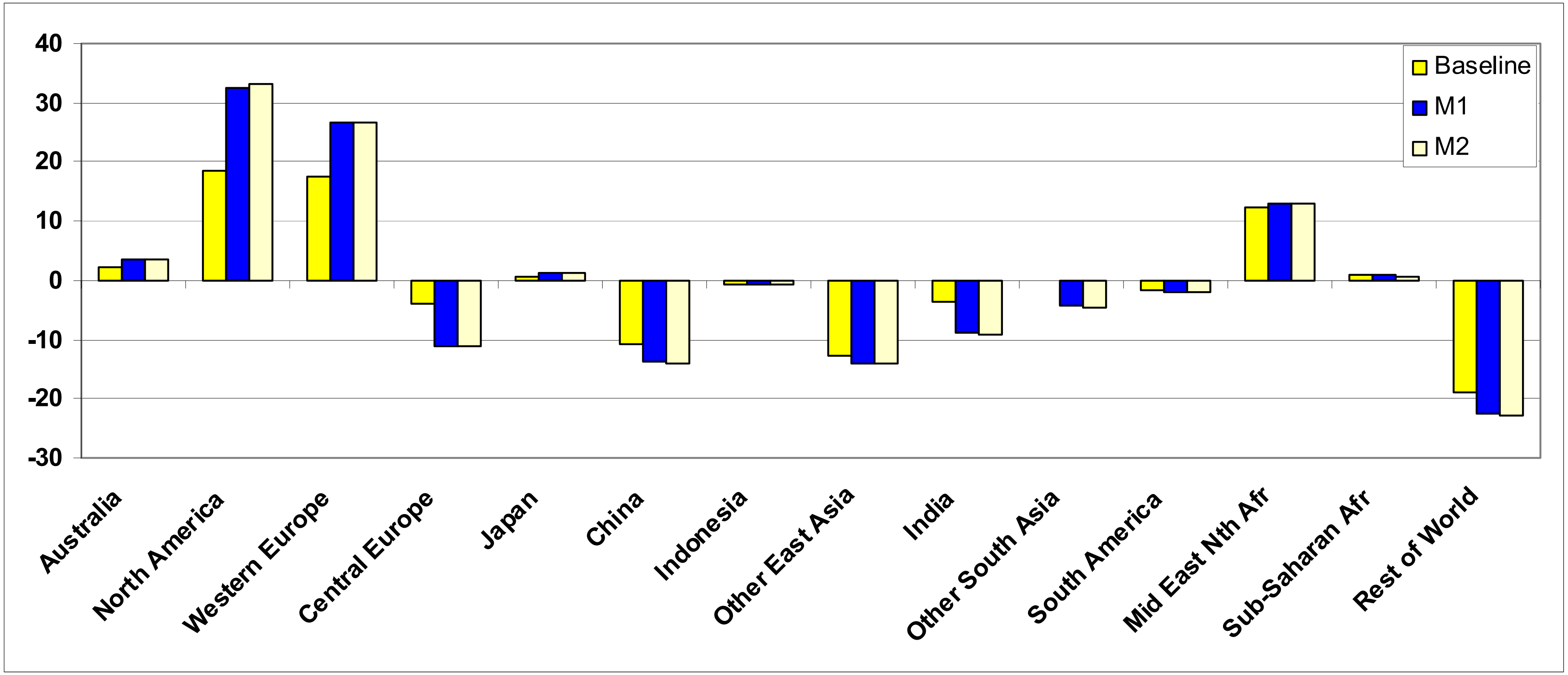


Figure 6: M2 Departures from Base Line Population, %

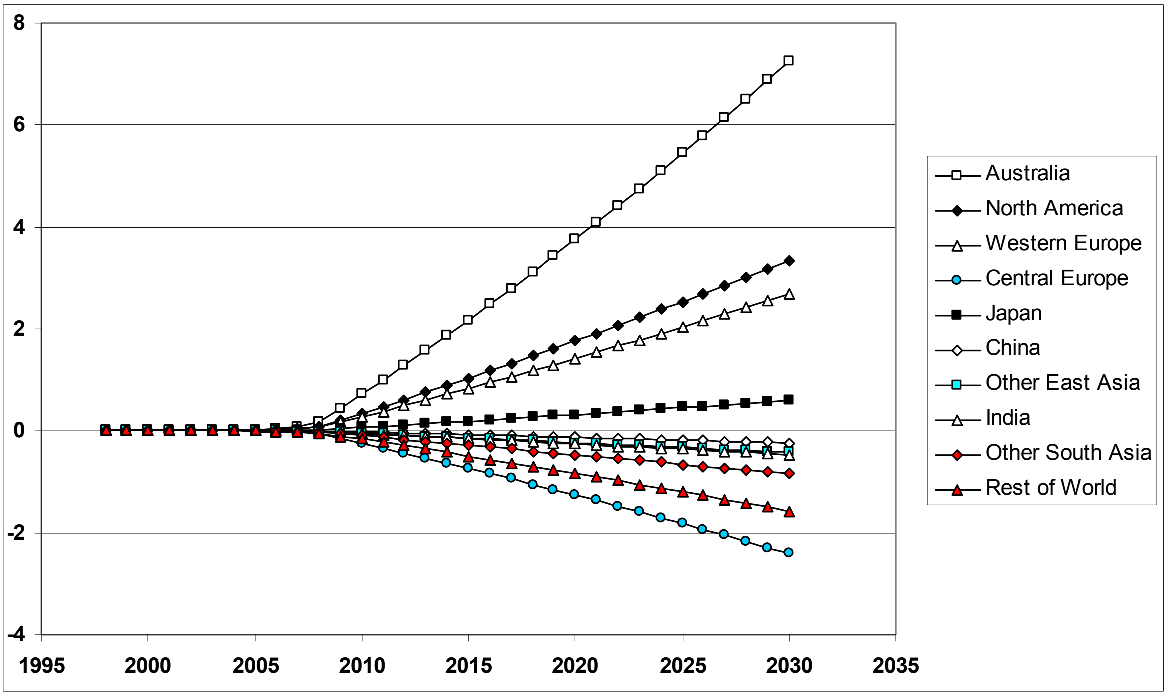


Figure 7: Departures from Base Line Labour Forces, 2030, in %

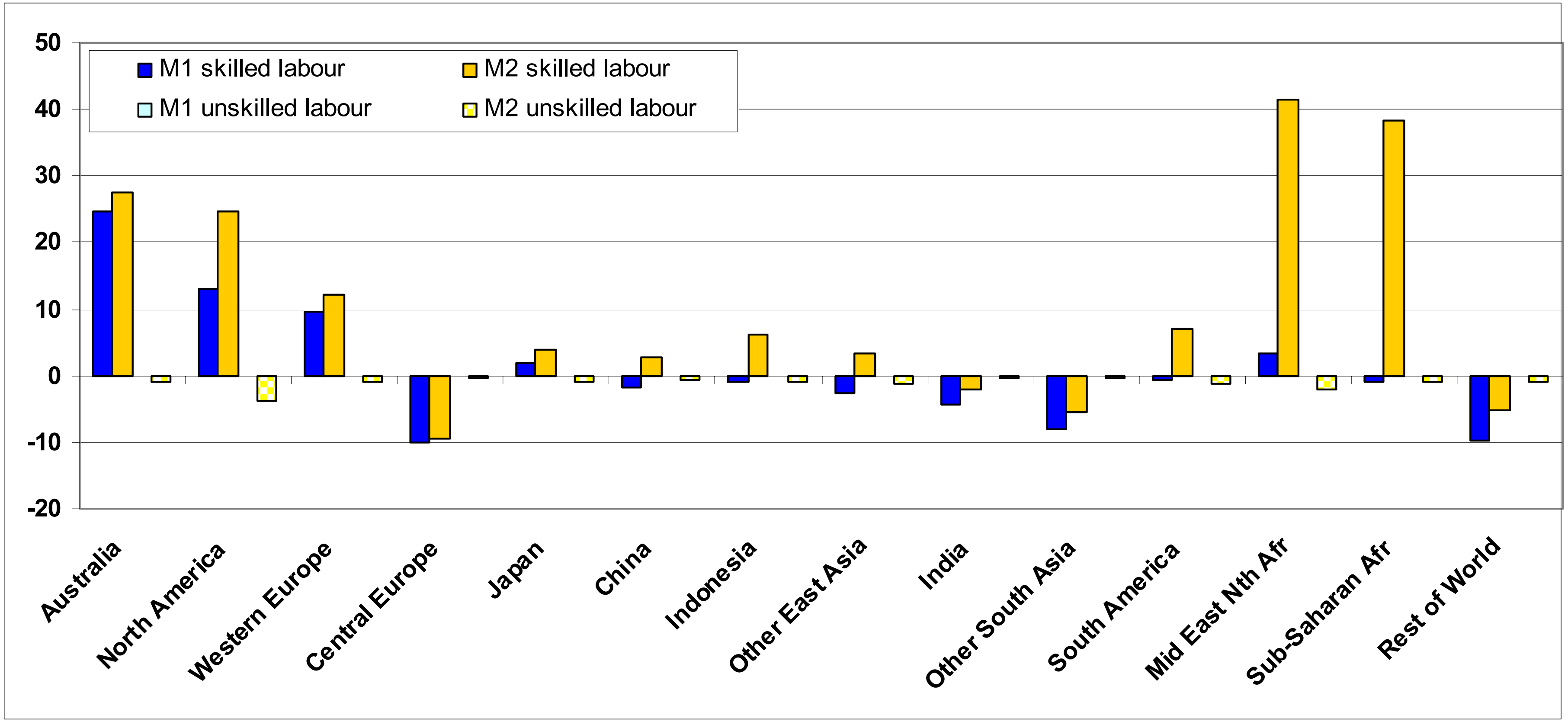


Figure 8: Regional GDP
$US trillions

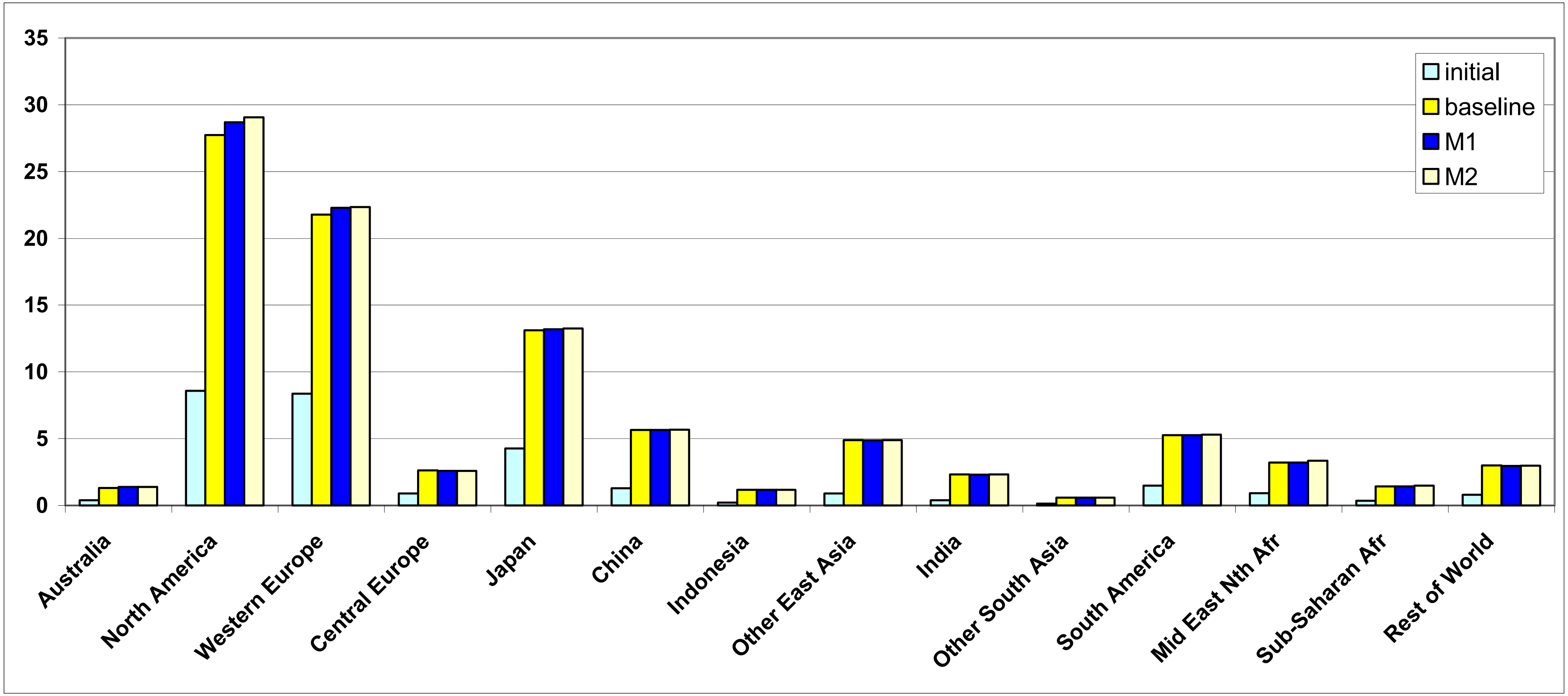


Figure 9: GDP, M1 Departures from Base Line, %

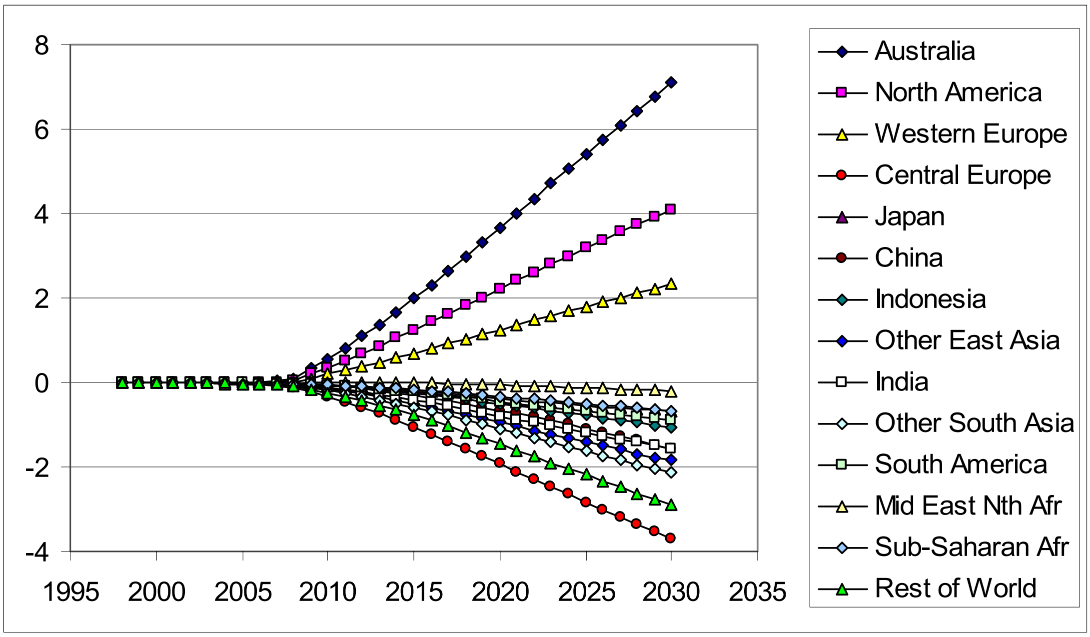


Figure 10: GDP, M2 Departures from Base Line, %

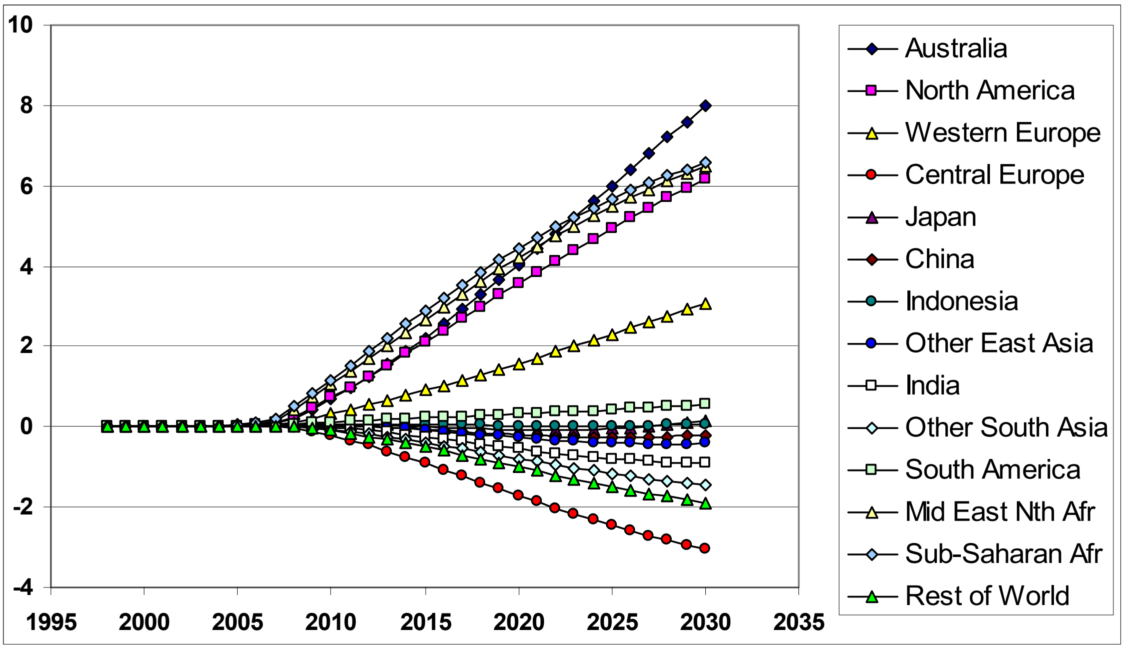


Figure 11: Departures from Base Line Wage Rates, 2030, in %

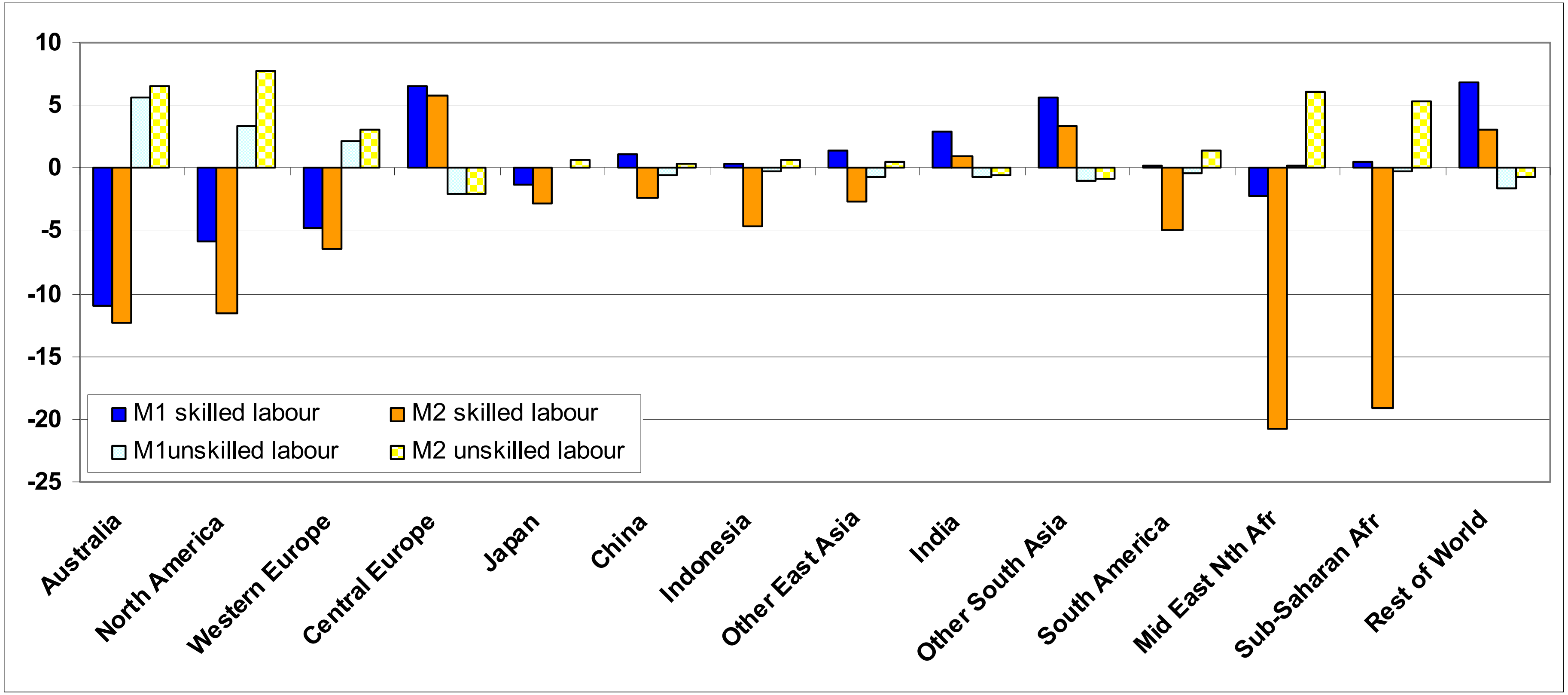


Figure 12: Australian Wage Convergence in M2

(Wages, US$ '000)

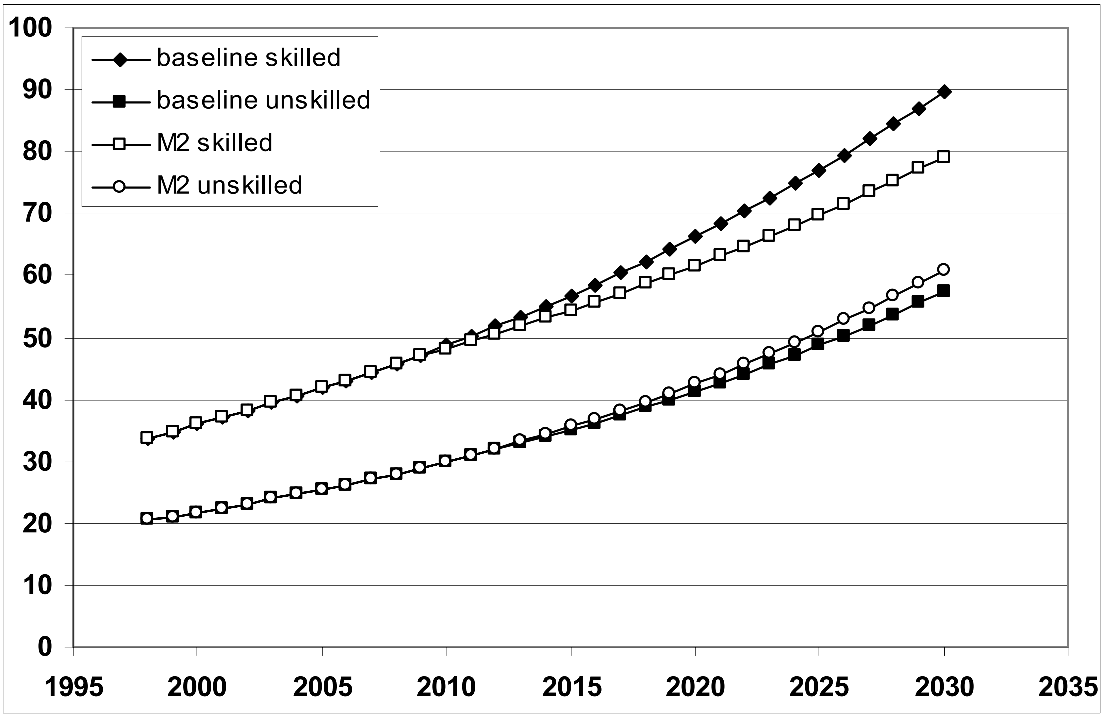


Figure 13: North American Wage Convergence in M2

(Wages, US$ '000)

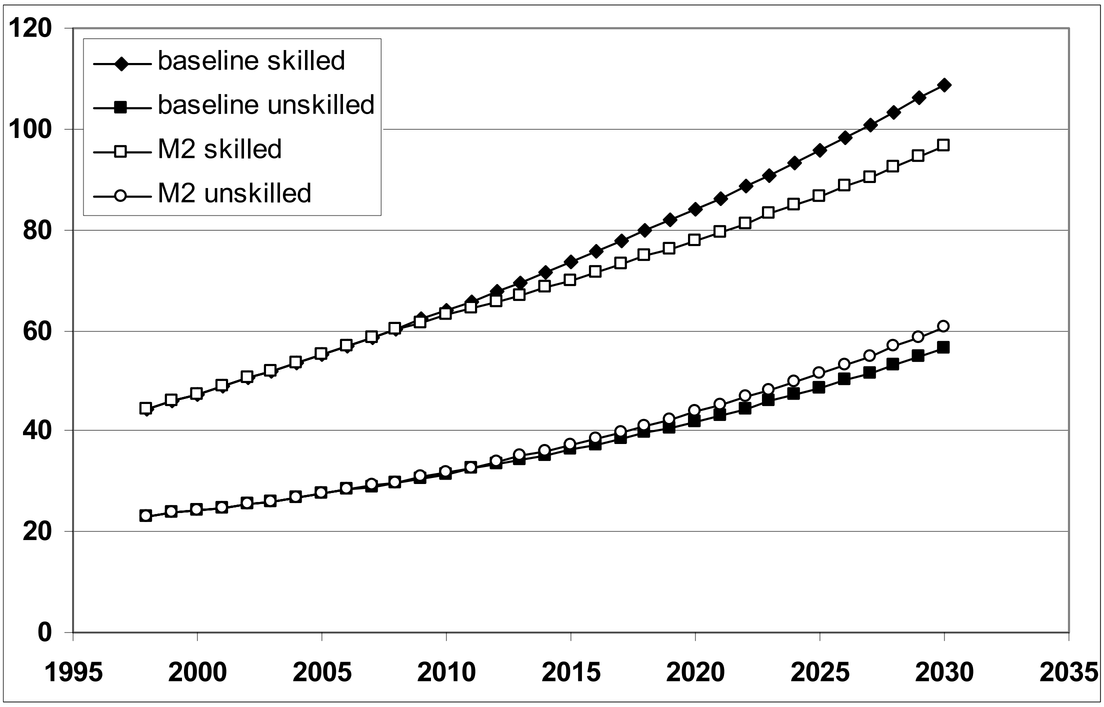


Figure 14: Western European Wage Convergence in M2

(Wages, US$ '000)

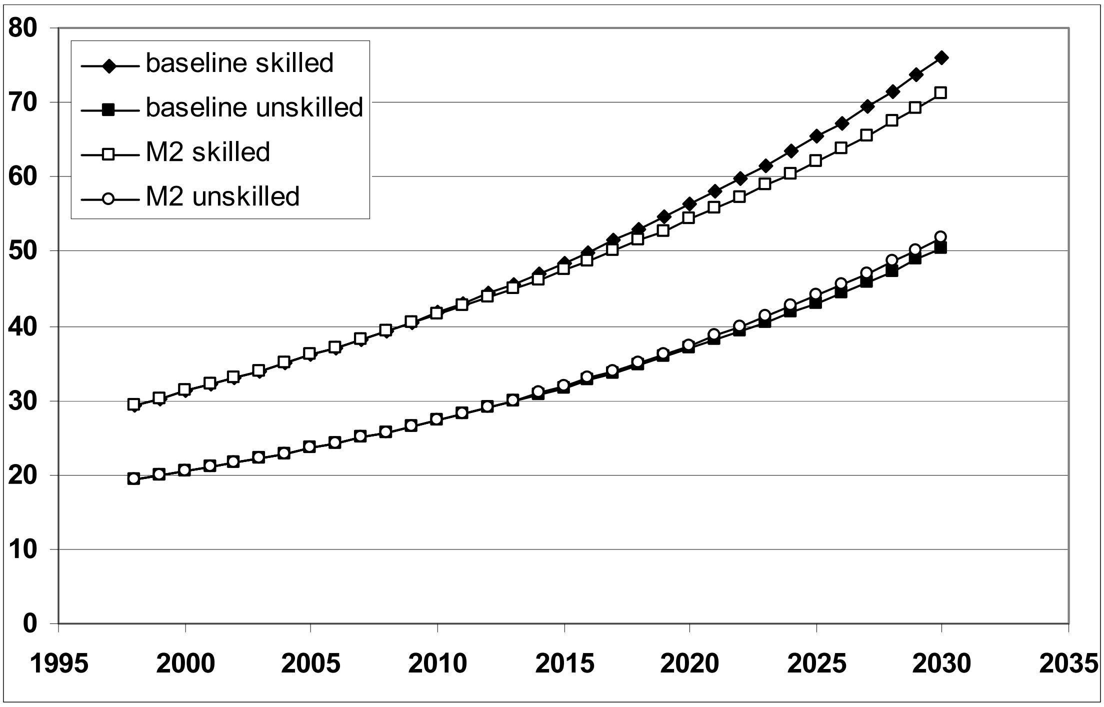


Table 1: Ratio of Estimated Migrant Stocks to Recorded Annual Migration Flows in Australia, North America and Western Europe, %

Sending Region	Host Region: Australia	North America	Western Europe	Average
Australia	0	3.025201	8.989963	6.007582
North America	2.644216	0	7.029465	4.836841
Western Europe	1.818013	1.18226	0	1.500137
Central Europe, FSU	0.478116	1.322667	4.478153	2.092979
Japan	0.115782	0.439094	0.303218	0.286031
China	13.56907	13.60295	5.251	10.80767
Indonesia	23.54253	2.389023	3.093284	9.674946
Other East Asia	9.946415	13.15915	7.982539	10.3627
India	2.571327	4.771925	3.421751	3.588334
Other South Asia	2.173844	4.321764	1.358993	2.6182
South America	3.569294	2.323215	0.939522	2.277344
Mid East Nth Africa	1.091152	0.655403	3.334289	1.693615
Sub-Saharan Africa	4.961956	4.284872	1.760036	3.668955
Rest of World	44.56669	52.44887	220.8577	105.9578

Sources: -Migration Policy Institute (2004), "Global Data Center" The Migration Information Source, Washington. (http://www.migrationinformation.org/GlobalData);
-DIMIA (2001), "Immigration Federation to Century's End 1901-2000". Statistics Section, Department of Immigration and Multicultural Affairs.

Table 2: Estimated Annual Flow of Migrants by Sending and Host Region

Sending Region	Host Region: Australia	North America	Western Europe	Central Europe, FSU	Japan	China	Indonesia	Other East Asia	India	Other South Asia	South America	Mid East Nth Africa	Sub-Saharan Africa	Rest of World	**Total**
Australia	0	10000	13855	5184	246	532	60	583	951	949	192	3244	3076	1638	40509
North America	3722	0	88730	45687	2959	6407	725	7024	11453	11433	5894	40466	48162	14611	287272
Western Europe	20326	48139	0	81888	2540	5501	623	6031	9834	9816	5143	32393	22530	1843	246606
Central Europe, FSU	6000	60451	366672	0	3771	8166	924	8953	14598	14573	7635	48087	33445	2736	576012
Japan	50	1500	800	2000	0	545	62	597	974	972	65	3076	1170	109	11921
China	12689	100626	30000	50000	5253	0	1287	12471	20334	20298	1357	64213	24433	2278	345240
Indonesia	2491	2000	2000	3000	515	1115	0	1223	1994	1990	133	6296	2396	223	25377
Other East Asia	10197	106723	50000	60000	6324	13695	1550	0	24481	24438	1634	77311	29417	2742	408513
India	4298	63103	34947	41136	3720	8056	912	8832	0	14376	961	45477	17304	1613	244735
Other South Asia	3628	57050	13855	29962	2710	5868	664	6433	10489	0	700	33124	12604	1175	178260
South America	2000	47169	7382	8286	308	667	75	731	1192	1190	0	4104	4157	505	77765
Mid East Nth Africa	5742	26979	114410	42026	3553	7694	871	8436	13754	13730	919	0	20187	1532	259832
Sub-Saharan Africa	9293	47669	50630	118467	4053	8776	993	9622	15688	15661	1070	61849	0	1518	345287
Rest of World	22303	245228	93851	50539	3030	6562	743	7195	11731	11710	5238	41138	46852	0	546119
Total	102739	816636	867130	538173	38982	73584	9489	78130	137473	141137	30941	460777	265735	32523	3593448

Sources: -Migration Policy Institute (2004), "Global Data Center" The Migration Information Source, Washington. (http://www.migrationinformation.org/GlobalData);
-DIMIA (2001), "Immigration Federation to Century's End 1901-2000". Statistics Section, Department of Immigration and Multicultural Affairs.
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Table 3: Wages per Worker at Market Exchange Rates (MER) and Purchasing Power Parity (PPP)[a]

(US$ '000 per year)

	Unskilled		Skilled	
	MER	PPP	MER	PPP
Australia	20.5	19.6	33.8	32.3
North America	23.1	27.9	44.5	53.7
Western Europe	19.5	16.7	29.5	25.3
Central Europe, FSU	2.4	4.8	2.1	4.3
Japan	32.4	23.3	43.3	31.1
China	0.9	3.7	2.4	9.8
Indonesia	0.7	2.3	1.0	3.3
Other East Asia	2.5	7.9	5.5	17.5
India	0.4	1.4	0.7	2.5
Other South Asia	0.3	0.9	0.8	2.0
South America	4.4	7.3	11.5	18.8
Mid East Nth Africa	2.9	5.2	10.0	17.8
Sub-Saharan Africa	0.9	3.2	12.7	46.6
Rest of World	3.1	3.3	6.2	6.6
Mean	8.1	9.1	14.6	19.4
Standard Deviation	10.8	8.9	16.1	16.6
Coefficient of Variation	1.32	0.98	1.11	0.86

a Wages, denominated in thousands of US dollars per worker, are values of firms' purchases at agents' prices.
Sources: -GTAP Database;
-Liu, J. et al (1998), "Disaggregating Labour Payments by Skill Level in GTAP". GTAP Technical Paper No. 11, Purdue University. (www.gtap-agecon.purdue.edu/resources);
-World Bank (2000), "Global network development database: macro time series", World Bank Washington DC, (www.worldbank.org/research/growth/GDNdata.html).

Table 4: Base Line Projections of Labour Force Size and Structure

	Labour force[a]		% Female		% 40+	
	Initial	**2030**	**Initial**	**2030**	**Initial**	**2030**
Australia	8	10	37	40	42	48
North America	182	250	40	42	42	47
Western Europe	184	165	40	44	47	55
Central Europe	181	148	47	46	44	53
Japan	61	55	37	37	58	65
China	570	592	37	36	34	47
Indonesia	87	130	38	38	40	54
Other East Asia	127	178	41	40	37	51
India	356	594	27	28	36	47
Other South Asia	134	265	28	28	32	44
South America	123	193	38	39	33	48
Mid East Nth Afr	103	176	24	23	30	42
Sub-Saharan Afr	150	349	28	29	29	36
Rest of World	79	131	36	34	38	48

a Measured in full time equivalent workers.
Source: Projection using the demographic model described in the text, as presented in detail by Chan and Tyers (2005).

Table 5: Base Line Non-Working Aged Dependency Ratios

Per cent	Non-working aged/working	
	Initial	**2030**
Australia	35	55
North America	24	37
Western Europe	42	61
Central Europe	29	41
Japan	32	47
China	19	44
Indonesia	9	16
Other East Asia	9	22
India	12	23
Other South Asia	9	17
South America	16	28
Mid East Nth Africa	15	33
Sub-Saharan Africa	13	15
Rest of World	15	27

Source: Base period statistics constructed from population statistics from United Nations (2003) and simulation results from the demographic model described in the text.

Table 6: Base Line Real GDP and per Capita Income Projections to 2030

	% change 2030 over 1997		Implied *average* annual growth rate, %/yr	
	Real GDP	Real per capita income	Real GDP	Real per capita income
Australia	262	178	4.0	3.1
North America	253	171	3.9	3.1
Western Europe	159	177	2.9	3.1
Central Europe & FSU	205	210	3.4	3.5
Japan	166	217	3.0	3.6
China	340	400	4.6	5.0
Indonesia	490	371	5.5	4.8
Other East Asia	529	373	5.7	4.8
India	565	292	5.9	4.2
Other South Asia	430	127	5.2	2.5
South America	293	149	4.2	2.8
Mid East & Nth Africa	280	104	4.1	2.2
Sub-Saharan Africa	360	114	4.7	2.3
Rest of World	336	159	4.6	2.9

Source: The base line projection described in the text.

Table 7: Transformation (Skill Acquisition) Rates[a]

Per cent

	Base line	***M2*** 2010
Australia	0.12	0.17
North America	0.30	0.52
Western Europe	0.13	0.18
Central Europe	0.12	0.13
Japan	0.15	0.19
China	0.08	0.11
Indonesia	0.10	0.14
Other East Asia	0.11	0.16
India	0.08	0.09
Other South Asia	0.07	0.09
South America	0.10	0.16
Mid East Nth Africa	0.08	0.19
Sub-Saharan Africa	0.04	0.09
Rest of World	0.10	0.14

a The proportion, ρ, of production worker families that are transformed into professional families each year (equation 12).

Source: Economy-wide skill subdivisions from the ILO Yearbook, various issues, and simulations constructed using the model described in the text.

Table 8: Skilled and Unskilled Labour Force, Baseline, *M1* and *M2*

(Millions)

	Baseline initial		Baseline 2030		M1 2030		M2 2030	
	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled
Australia	2.3	5.3	2.7	6.0	3.4	6.0	3.4	6.0
North America	47.8	134.2	62.1	174.8	69.7	174.8	76.8	168.2
Western Europe	56.5	127.4	51.2	113.2	55.9	113.2	57.1	112.1
Central Europe	45.1	136.4	39.8	114.9	35.9	114.9	36.2	114.6
Japan	19.3	42.0	17.8	37.4	18.1	37.4	18.5	37.1
China	71.1	498.7	79.2	513.4	77.8	513.4	81.4	509.8
Indonesia	9.3	78.2	13.8	114.9	13.7	114.9	14.6	114.0
Other East Asia	19.9	107.1	28.5	145.1	27.8	145.1	29.4	143.5
India	36.9	319.2	65.7	523.2	63.0	523.2	64.4	521.6
Other South Asia	13.8	120.1	28.2	235.0	26.0	235.0	26.7	234.2
South America	17.7	105.0	28.3	163.0	28.1	163.0	30.2	160.9
Mid East Nth Afr	5.6	97.0	9.8	171.1	10.1	171.1	13.7	167.5
Sub-Saharan Afr	3.5	146.9	7.9	336.9	7.9	336.9	10.9	333.8
Rest of World	12.8	65.8	20.6	108.3	18.6	108.3	19.5	107.3

Source: GTAP 5 Database, base period labour force estimates from Chan and Tyers (2006) and simulations constructed using the model described in the text.

Table 9: Changes in 2030 Non-Working Aged Dependency Ratios[a]

Percentage points	Non-working aged/working	
	M1	***M2***
Australia	-1.83	-1.89
North America	-0.29	-0.32
Western Europe	-0.95	-0.97
Central Europe	0.49	0.50
Japan	-0.15	-0.15
China	0.03	0.03
Indonesia	0.00	0.00
Other East Asia	0.01	0.01
India	0.00	0.01
Other South Asia	-0.02	-0.02
South America	0.01	0.01
Mid East Nth Africa	0.00	0.01
Sub-Saharan Africa	0.00	0.00
Rest of World	-1.83	-1.89

a These are percentage point changes in the non-working aged dependency ratios listed in Table 5.
Source: Simulations of the model described in the text.

Table 10: Skilled and Unskilled Wages, Baseline, *M1* and *M2*

(US$ '000 per year)

	baseline initial		baseline 2030		***M1*** 2030		***M2*** 2030	
	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled
Australia	33.8	20.5	89.8	57.4	80.3	60.5	79.1	61.0
North America	44.5	23.1	108.7	56.4	102.6	58.2	96.5	60.6
Western Europe	29.5	19.5	75.9	50.4	72.4	51.5	71.2	51.9
Central Europe	2.6	2.2	7.7	6.8	8.2	6.7	8.1	6.7
Japan	43.3	32.4	114.6	86.9	113.1	86.9	111.5	87.4
China	2.4	0.9	7.7	3.1	7.8	3.1	7.6	3.1
Indonesia	1.6	0.7	5.0	2.1	5.0	2.1	4.7	2.1
Other East Asia	5.5	2.5	19.1	8.9	19.3	8.9	18.6	9.0
India	0.7	0.4	1.8	1.0	1.8	1.0	1.8	1.0
Other South Asia	0.8	0.3	1.5	0.7	1.6	0.7	1.6	0.7
South America	11.5	4.4	25.0	10.1	25.0	10.1	23.8	10.2
Mid East Nth Afr	20.1	2.8	39.3	5.5	38.5	5.5	31.4	5.8
Sub-Saharan Afr	12.7	0.9	23.6	1.6	23.7	1.6	19.2	1.7
Rest of World	6.2	3.1	14.2	7.2	15.2	7.0	14.6	7.1

Source: The base line columns are from Table 3 and the projections are constructed using the model described in the text.

Table 11: Effects of Expanded Skilled Migration on Real GNP per Capita

	% departure from base line, 2030	
	M1	***M2***
Australia	-0.5	-0.4
North America	0.6	1.8
Western Europe	0.0	0.2
Central Europe & FSU	0.3	0.2
Japan	0.3	0.6
China	0.4	1.0
Indonesia	0.4	0.8
Other East Asia	0.3	0.9
India	0.1	0.2
Other South Asia	-0.3	-0.1
South America	0.0	0.8
Mid East & Nth Africa	0.5	4.9
Sub-Saharan Africa	-0.1	5.5
Rest of World	0.0	0.5

Source: The base line and M1 and M2 projections described in the text.

Appendix 1: Regional Composition

1. AUSTRALIA

2. REST OF WORLD (RoW)
Afghanistan Albania Andorra Anguila Antigua & Barbuda Aruba Bahamas Barbados
Belize Bermuda Bosnia and Herzegovina Brunei British Virgin Islands
Cambodia Croatia Cyprus Cayman Islands Costa Rica Cuba Dominica
Dominican Republic El Salvador Faroe Islands Federated States of Micronesia
Fiji French Polynesia Grenada Guatemala Gibraltar Greenland Guadeloupe Haiti
Honduras Jamaica Kiribati Lao People's Democratic Republic Macau Malta
Marshall Islands Monaco Mongolia Myanmar Nauru New Caledonia Netherlands Antilles
New Zealand Nicaragua Panama Papua New Guinea Saint Kitts and Nevis Saint Lucia
Saint Vincent and the Grenadines San Marino Solomon Islands The former Yugoslav Republic of Macedonia
Tonga Trinidad and Tobago Tuvalu Vanuatu Western Samoa Yugoslavia

3. CHINA
China Hong Kong Taiwan

4. JAPAN

5. EAST ASIA
Korea Malaysia Philippines Singapore Thailand Vietnam

6. INDONESIA

7. INDIA

8. OTHER SOUTH ASIA (OS_ASIA)
Bangladesh Bhutan Maldives Nepal Pakistan Sri Lanka

9. NORTH AMERICA (NAM)
American Samoa Canada Guam Mexico Northern Mariana Islands
United States of America

10. SOUTH AMERICA (SAM)
Argentina Bolivia Brazil Chile Colombia Ecuador Peru
Venezuela Uruguay

11. WESTERN EUROPE (WEU)
Belgium Denmark Finland France French Guiana Germany Greece
Iceland Ireland Italy Leichtenstein Luxembourg Martinique
Netherlands
Norway Portugal Reunion Spain Sweden Switzerland
United Kingdom

12. CENTRAL EUROPE & FORMER USSR (CEU_FSU)
Armenia Azerbaijan Belarus Bulgaria Czech Republic Estonia Georgia Hungary Kazakhstan
Kyrgyzstan Latvia Lithuania Poland Republic of Moldova Romania
Russian Federation Slovakia Slovenia Tajikistan Turkmenistan Ukraine Uzbekistan

13. MIDDLE EAST & NORTH AFRICA (ME_NA)
Algeria Bahrain Egypt Iraq Islamic Republic of Iran Israel Jordan Kuwait
Lebanon Libyan Arab Jamahiriya Morocco Oman Qatar Saudi Arabia Syrian Arab Republic
Tunisia Turkey United Arab Emirates Yemen

14. SUB-SAHARAN AFRICA (SSAFR)
Angola Benin Botswana Burkina Faso Burundi Cameroon Cape Verde Central African
Republic Chad Comoros Congo Cote d'Ivoire Djibouti Equatorial Guinea Eritrea
Ethiopia Gabon Gambia Ghana Guinea Guinea-Bissau Kenya
Lesotho Liberia Madagascar Mali Malawi Mauritania Mauritius Mayotte Mozambique
Namibia Niger Nigeria Rwanda Sao Tome and Principe Senegal Seychelles
Sierra Leone Somalia Sudan South Africa Swaziland Tanzania Togo
Uganda Zaire Zambia Zimbabwe