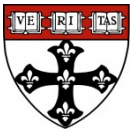

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Demography, Unemployment, Automation, and Digitalization: Implications for the Creation of (Decent) Jobs, 2010–2030

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Demography, Unemployment, Automation, and Digitalization: Implications for the Creation of (Decent) Jobs, 2010–2030[1]

David E. Bloom, Mathew J. McKenna, and Klaus Prettner

Abstract

Globally, an estimated 734 million jobs will be required between 2010 and 2030 to accommodate recent and ongoing demographic shifts, account for plausible changes in labour force participation rates, and achieve target unemployment rates of at or below 4 percent for adults and at or below 8 percent for youth. The facts that i) most new jobs will be required in countries where "decent" jobs are less prevalent and ii) workers in many occupations are increasingly subject to risks of automation further compound the challenge of job creation, which is already quite sizable in historical perspective. Failure to create the jobs that are needed through 2030 would put currently operative social security systems under pressure and undermine efforts to guarantee the national social protection floors enshrined in the Sustainable Development Goals (SDGs).

1. Introduction

Between 2010 and 2030, global labour markets will face the daunting task of generating roughly three-quarters of a billion new jobs. As calculated in this paper, this is the estimated number of jobs required to absorb the projected 21 percent increase in the world's working-age population, accommodate a trend of increasing labour force participation (predominantly among the female population as fertility declines), and allow for a target reduction in youth unemployment rates to no more than 8 percent and adult unemployment rates to no more than 4 percent. Although the scale of this job creation challenge will subsequently abate due to declining rates of fertility and population growth, job creation requirements in the coming two decades predominantly reflect the past two decades of population growth (Bloom and Freeman 1986), which was substantial by historical standards.

Two key features of the global economic landscape further magnify the challenge of job creation. First, roughly 91 percent of the new jobs will be required in low- and lower-middle-income countries, where traditions of "decent work" are not well entrenched. Indeed, with respect to the need to create decent jobs, the magnitude of the challenge facing the world is without historical precedent. Second, rapid progress has occurred in the area of automation over the last decade, whereby many jobs previously deemed to be nonautomatable are now regarded

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as having a high likelihood of being automated over the next two decades (Ford 2015; Arntz et al. 2017; Frey and Osborne 2017).

This paper explores the number and quality of jobs that need to be created to accommodate recent and ongoing demographic shifts and account for plausible changes in labour force participation and unemployment rates. We examine these patterns globally; by geographic region, country income group, and human development category; and over time. We distinguish the effects of demographic change on job creation that reflect accounting from those that reflect behaviour, and we address the implications of automation.

Section 2 sets out the standard accounting identities we use to relate population, labour force, unemployment, and employment; briefly overviews the data upon which we rely; and describes our estimates. Section 3 distinguishes between jobs and decent jobs and further explores the nature and magnitude of the job creation challenges facing the world. Section 4 discusses some key behavioural links between demographics and employment, most notably, the effects of fertility and education on labour force participation. Section 5 highlights the potential effects of automation on job generation, while Section 6 presents some final thoughts and conclusions.

2. Framework, data, and estimates

Accounting identities

We let *N* be the population size, *LF* the size of the labour force, *NLF* the number of people not in the labour force, *E* the number of employees, *U* the number of unemployed people,[2] *LFPR* the labour force participation rate, and *UR* the unemployment rate. Furthermore, we use the indices *a, i, k,* and *t* to refer to age groups, countries, sex, and time (measured in years), respectively. Using this notation, we can state the following standard accounting identities and definitions on which many of the calculations reported later in this section rely:

$$N_{a,i,k,t} = LF_{a,i,k,t} + NLF_{a,i,k,t}, \quad \textbf{(1a)}$$

$$LF_{a,i,k,t} = E_{a,i,k,t} + U_{a,i,k,t}, \quad \textbf{(1b)}$$

$$LFPR_{a,i,k,t} = \frac{LF_{a,i,k,t}}{N_{a,i,k,t}}, \quad \textbf{(1c)}$$

$$UR_{a,i,k,t} = \frac{U_{a,i,k,t}}{LF_{a,i,k,t}}. \quad \textbf{(1d)}$$

Following standard convention, we treat the age range 15–64 as the working ages, which we further divide into youth working ages (15–24) and adult working ages (25–64).

Equations (1a–d) imply that worldwide employment at time *t* can be expressed as

[2] The ILO defines unemployed people as all those who are without work, are currently available for work, and have actively sought work over the past four weeks.

$$E_t = \sum_a \sum_i \sum_k [(N_{a,i,k.t} \times LFPR_{a,i,k.t}) \times (1 - UR_{a,i,k.t})]. \quad \textbf{(2)}$$

We use the first difference of equation (2) to calculate changes in employment, which we do over two broad periods: 1990–2010 and 2010–2030. Equation (2) suggests that changes in employment over time are due to changes in any of three sets of variables—population, labour force participation rates, or unemployment rates—and thereby offers a framework for decomposing past and future projections of employment. For example, by holding unemployment rates and labour force participation rates constant at their time *t* values, we can observe the change in employment at time *t*+1 that is attributable to changes in the population size. Doing so allows us to identify the primary demographic drivers behind historical employment changes and provides insight into the nature of future employment needs.

This decomposition further helps to distinguish between accounting and behavioural effects. A direct accounting link exists between changes in population and employment because a portion of the additional population will directly enter employment assuming constant age- and gender-specific labour force participation rates and unemployment rates. By contrast, changes in age- and gender-specific labour force participation rates reflect behavioural effects such as those due to changes in fertility or education (Besamusca et al. 2015; Bloom et al. 2009; Prettner et al. 2013). In 1990–2010, changes in the unemployment rate reflect historical shifts; in 2010–2030, these changes reflect an assumed target of reducing unemployment rates.[3]

Data summary

Our analysis relies primarily on three data sets: the United Nations' *World Population Prospects: The 2015 Revision* (United Nations 2015b), the International Labour Organization's ILOSTAT database (ILO 2013b), and the ILO's *Global Employment Trends 2014: Supporting Data Sets* (ILO 2014). We rely on *World Population Prospects* for population estimates and projections, using the medium-fertility scenario projections for 2015–2030; the ILOSTAT database for labour force participation rate estimates and projections; and *Global Employment Trends* for historical unemployment rates through 2010.

At the outset, four items are worth noting. First, this paper's estimates refer to the number of jobs needed, assuming no multiple job holding. Second, they do not distinguish between full- and part-time jobs. Third, the estimates refer only to employment of the 15–64 year-old population. These estimates could be biased downward as the 65-plus age group may very well increase labour force participation rates as mortality rates decrease (Bloom et al. 2014; Bloom et al. 2015; Lee and Mason 2010b). Accounting for the 65-plus age group's employment needs would require not only increasing the number of jobs, but also redesigning the employment structure to accommodate older workers who may not be capable of working as intensively, yet cannot retire due to needing higher savings for a longer life. Conversely, these estimates could be biased

[3] We use targets of at or less than 4 percent for adult unemployment and at or less than 8 percent for youth unemployment. For countries that are already below the 4-percent (55 countries) or 8-percent (28 countries) threshold in 2010, we simply carry forward these values.

upward due to the expansion of schooling and increased educational attainment (KC et al. 2010; Lutz and KC 2013). The ILO projections may not fully capture these effects because the model does not explicitly account for educational attainment.

Fourth, the data sets this analysis uses are not perfectly aligned with respect to the countries included. Among the countries in the *World Population Prospects* database (United Nations 2015b), the ILOSTAT database (ILO 2013b) has no available data for 10 on labour force participation rates.[4] Most of these countries are small island nations, with the notable exceptions of South Sudan and the State of Palestine. We exclude these countries from our analysis as the lack of labour force participation rates prevents us from calculating employment. Because the countries excluded from our analysis accounted for only 0.6 percent of the global population in 2010, the impact on the accuracy of our estimates should be minimal.

[4] See footnote 2 of Table 1 for the list of countries for which labour force participation rates are unavailable.

Table 1: Summary statistics of labour force participation rates and unemployment rates by age, sex, and region (percent)						
	Labour force participation rates			**Unemployment rates**		
	1990	**2010**	**2030**	**1990**	**2010**	**2030 (targeted)**
Global						
Age group						
15–64	71.2	68.4	69.4	6.4	6.1	4.0
15–24	59.6	47.7	47.3	11.9	12.9	7.6
25–64	76.4	76.1	76.1	4.5	4.6	3.2
Sex						
Male	84.7	81.4	82.5	6.2	5.9	3.8
Female	57.3	55.2	55.8	6.7	6.6	4.0
Region						
Arab States	51.2	51.9	53.7	12.3	10.2	5.2
East Asia and the Pacific	81.5	75.6	76.3	5.0	4.3	3.6
Europe and Central Asia	67.1	62.1	64.1	9.3	10.6	4.8
Latin America and the Caribbean	64.0	70.3	73.0	8.1	7.3	4.3
South Asia	62.6	58.7	60.4	4.5	4.4	3.4
Sub-Saharan Africa	71.2	71.7	73.6	8.4	7.8	4.5

Notes:

1) Values represent net effects from beginning to end of the period and do not reflect movement in the intervening years.
2) Global estimates represent approximately 99.4 percent of the global population due to the lack of labour force participation rates for 10 countries: Antigua and Barbuda, Aruba, Curacao, Federated States of Micronesia, Grenada, Kiribati, Mayotte, Seychelles, South Sudan, and State of Palestine.
3) Regions are defined as in the *Human Development Report 2014* (UNDP 2014). The regions included here represent approximately 82 percent of the global population in 2010. In 1990–2010, however, they represented 93 percent of global population growth. In 2010–2030, they will represent 104 percent of population growth, indicating declining working-age populations in countries not belonging to any of these regions. A total of 54 countries do not belong to any of these regions, with the 10 largest (ranked by working-age population in 2010) being the United States, the Russian Federation, Japan, Germany, France, the United Kingdom, Italy, the Republic of Korea, Spain, and Poland.
4) Source: Authors' work derived from United Nations (2015b) and ILO (2013b)

Table 2: Estimated changes in population, labour force, and employment in 1990–2010 and 2010–2030, by age, sex, and region (millions)							
	Change in population		Change in labour force		Change in employment 1990–2010	Change in employment 2010–2030	
	1990–2010	2010–2030	1990–2010	2010–2030		Constant 2010 unemployment rate	Unemployment rate targets of at or less than 4 percent for adults and at or less than 8 percent for youth
Global							
Age group							
15–64	1,300	940	799	695	757	659	734
15–24	219	63	-13	24	-17	19	53
25–64	1,100	877	812	668	773	640	681
Sex							
Male	652	490	476	430	452	411	451
Female	644	450	324	265	304	247	285
Region							
Arab States	96	104	51	60	47	53	62
East Asia and the Pacific	380	60	226	56	221	55	62
Europe and Central Asia	27	14	10	12	8	11	17
Latin America and the Caribbean	125	89	104	76	98	72	81
South Asia	397	367	206	240	198	233	238
Sub-Saharan Africa	187	346	135	263	126	245	261

Notes:

1) Values represent net effects from beginning to end of period and do not reflect movement in the intervening years.
2) Population numbers were obtained from the UN's *World Population Prospects: The 2015 Revision* (United Nations 2015b) and thus refer to 1 July for each year indicated. Numbers are based on the medium-fertility variant. Note that population growth is fairly sensitive to the variant used.
3) Global estimates represent approximately 99.4 percent of the global population due to the lack of labour force participation rates for 10 countries: Antigua and Barbuda, Aruba, Curacao, Federated States of Micronesia, Grenada, Kiribati, Mayotte, Seychelles, South Sudan, and State of Palestine.
4) Regions are defined as in the *Human Development Report 2014* (UNDP 2014). The regions included here represented approximately 82 percent of the global population in 2010. In 1990–2010, however, they represented 93 percent of global population growth. In 2010–2030, they will represent 104 percent of population growth, indicating declining working-age populations in countries not belonging to any of these regions. A total of 54 countries do not belong to

any of these regions, with the 10 largest (ranked by working-age population in 2010) being the United States, the Russian Federation, Japan, Germany, France, the United Kingdom, Italy, the Republic of Korea, Spain, and Poland.

5) Source: Authors' work derived from United Nations (2015b) and ILO (2013b)

Job creation needs: Basic results

Between 2010 and 2030, approximately 734 million jobs need to be created to accommodate population growth, shifts in the population's age and sex composition, changing age- and sex-specific labour force participation rates, and achievement of target unemployment levels of at or less than 4 percent for adults and at or less than 8 percent for youth. This is almost the same number of jobs that were created between 1990 and 2010. In 1990–2010, population growth was the primary driver of employment growth; its effect was dampened somewhat by decreasing labour force participation rates, while changes in unemployment rates had little to no impact. In 2010–2030, population growth will remain the primary driver of employment growth, but general increases in labour force participation rates, a general shift in the age structure whereby the population concentrates more in higher-participation age groups, and targeted decreases in unemployment rates also contribute.

Changes in working-age population

Tables 1 and 2 summarize global changes in population and labour force participation rates, the labour force, unemployment rates, and employment by age, sex, and region. Focusing first on population, we see that the global working-age population increased by roughly 1.3 billion between 1990 and 2010. Projections show an additional increase of 940 million expected between 2010 and 2030. These numbers reflect growth of approximately 40 percent in 1990–2010 and 21 percent in 2010–2030. Looking at the growth rate in conjunction with the absolute value of changes in population highlights that while population growth is projected to slow considerably, the absolute number of people entering the working-age group will not fall off as sharply. While the rate of population growth may be cut in half in the later period, a considerable addition to the working-age population of roughly 72 percent of the observed addition from 1990–2010 will still occur.

Separating the total working-age population into youth and adult groups provides an interesting insight into how the composition of population growth will change. In 1990–2010, increases in the youth working-age population accounted for approximately 17 percent of total population growth. In 2010–2030, however, the proportion of the youth working-age population will drop to only 7 percent of total population growth. In fact, the projected increase in the youth working-age population in 2010–2030 is only roughly 29 percent of the increase experienced in 1990–2010. The projected increase in the adult working-age population in 2010–2030 is roughly 80 percent of the increase in 1990–2010.

This apparent divergence of population growth between the youth and adult working ages can have powerful implications for employment growth (Bloom et al. 2003). In 1990–2010, a larger proportion of additions to the working-age population were in the younger age groups, who tend to have lower labour force participation rates. Thus, while the increase in the overall working-age population was higher in 1990–2010, the increase in 2010–2030 concentrates more in high-participation age groups. Beyond labour force participation, unemployment rates also differ substantially between the two age groups, with youth unemployment rates tending to be considerably higher than adult unemployment rates.

Regionally disaggregating global population changes provides insight into the geographical concentration of population growth and highlights differences in the population trajectory among regions. Among the six regions in our analysis, all but one are projected to experience lower population growth rates in 2010–2030 than they did in 1990–2010. The one exception is sub-Saharan Africa, where the 76 percent growth experienced in 1990–2010 is expected to increase by 3 percentage points to an anticipated growth rate of 79 percent in 2010–2030. In terms of absolute numbers, the Arab States join sub-Saharan Africa in expecting a larger population increase in 2010–2030 than that experienced in 1990–2010. The Arab States are projected to add approximately 8 percent more people than in 1990–2010, while sub-Saharan Africa is expected to add approximately 85 percent more people.

The largest decrease in population growth among the six regions examined will likely occur in East Asia and the Pacific. The growth rate in 2010–2030 is projected to be only 4 percent compared with the 37 percent experienced in 1990–2010. In terms of the absolute number of additional people, only 16 percent of the growth experienced in 1990–2010 is expected to occur in 2010–2030. By contrast, the next largest decrease is projected to occur in Europe and Central Asia where we still expect approximately 52 percent of the growth experienced in 1990–2010.

The large gap between East Asia and the Pacific and sub-Saharan Africa in terms of anticipated changes in population growth highlights the difference between where each region lies along its growth trajectory. East Asia and the Pacific has already experienced the bulk of its population boom and is likely past its largest employment hurdle. Sub-Saharan Africa, however, continues to grow at an increasing rate and appears to be in the middle of its largest population boom. Thus, sub-Saharan Africa appears to have yet to face its most difficult job creation challenge.

Overall, the global working-age population is projected to grow by approximately 21 percent in 2010–2030, roughly half the growth rate experienced in 1990–2010. In terms of absolute numbers, additions to the working-age population are projected to account for almost three-quarters of those observed in 1990–2010 because of a larger population base in 2010 than in 1990. Additionally, the working-age population growth rate is projected to decline more sharply for youth than adults, exacerbating the challenge of job creation, as more growth will concentrate in higher-participation age groups.

Changes in labour force participation rates

In 1990–2010, global labour force participation rates decreased by approximately 2.7 percentage points; most of this shift is attributable to a decline among youth. By 2030, the overall participation rate is projected to rebound slightly, while the youth participation rate continues to decrease (though at a substantially reduced pace).

In 2010–2030, the ILO projects the global labour force participation rate to be somewhat flat, with a correspondingly small implication for the need for global job creation. At the global level, three forces influence the labour force participation rate: country- and age-specific labour force

participation rates[5], country age structures, and the distribution of the working-age population across countries. As we show later, the stability of overall participation rates does not reflect underlying stability in these three sets of influences. During 2010–2030, countries with lower labour force participation rates are expected to gain in population share. The negative effect that this would normally have on the global labour force participation rate is offset by a global tendency for age-specific labour force participation rates to increase and for increased population shares in the ages with higher labour force participation.[6]

A closer look at the decrease in global labour force participation in 1990–2010 shows some sex and age-group differences. Comparing male and female rates, men experienced a steeper decline of 3.4 percentage points than women who experienced a decrease of 2 percentage points. The biggest dichotomy occurred between the youth and adult working-age populations. The youth labour force participation rate decreased by 11.8 percentage points, while the adult labour force participation rate only fell by 0.3 percentage points.

Decomposing changes in the global working-age labour force participation rate into its separate components suggests that decreasing age-specific labour force participation rates primarily drove decreases in the labour force participation rate. In fact, without a positive effect from a shifting age structure, the overall labour force participation rate would have fallen even further. This implies that a population shift occurred from the lower-participation youth group to the higher-participation adult group, partially offsetting the effect of decreasing age-specific labour force participation rates. The country share of working-age population also had a negative effect on overall labour force participation rates, indicating that population growth in 1990–2010 was somewhat more focused in countries where participation rates were already lower.

While the global labour force participation rate is projected to rebound marginally by 2030, it only reflects an increase of 0.9 percentage points. This increase will be slightly higher for male participation rates, which are projected to increase by 1.1 percentage points compared with female participation rates, which are projected to increase by 0.6 percentage points. The youth/adult split will be considerably closer than in the prior period. Youth participation rates are still expected to decline, but only by 0.5 percentage points. Adult participation rates are projected to remain nearly constant, only increasing by 0.02 percentage points.

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[5] The likelihood of labour-force participation changes over the life cycle. Labour force participation rates are typically highest for middle-aged cohorts, because these cohorts feature fewer members engaged in education relative to younger cohorts and fewer retirees than older cohorts.

[6] As explored further later in this paper, several factors, including but not limited to changes in the total fertility rate or changes in education, can influence age-specific labour force participation rates. These two factors are behavioural rather than accounting effects such as the shifting age structure. We utilize a decomposition analysis structured similarly to the decomposition described in the earlier section on accounting identities to tease out the separate impacts of behavioural and accounting effects on aggregate labour force participation rate projections. Further, in a later section, we will elaborate on the behavioural effects by attempting to isolate the separate effects of fertility and education on labour force participation rates.

Decomposition of labour force participation rate changes between 2010 and 2030 shows that changes in age-specific labour force participation rates are again projected to be the primary catalyst of changes in the overall participation rate. The force of the changes, however, is expected to occur in the opposite direction from that seen in the previous two decades. Shifts in the age structure are again projected to have a positive impact on labour force participation, as the adult group continues to make up a larger share of the working-age population. Changes in country shares of the working-age population are projected to have a large negative impact, indicating that population growth continues to be focused in countries with low participation rates.

Disaggregating by region, we find that in 1990–2010, three regions underwent decreasing labour force participation rates (East Asia and the Pacific, Europe and Central Asia, and South Asia) and three experienced increasing labour force participation rates (Arab States, Latin America and the Caribbean, and sub-Saharan Africa). Decomposing the changes in each region's labour force participation rate reveals some interesting regional differences. The Arab States is the only region where the largest effect came from shifting age structures. In fact, the positive effect of the shift in age structures was enough to fully offset the negative effect of decreasing age-specific labour force participation rates. The Arab States and sub-Saharan Africa are the only two regions where the country shares of working-age population had a positive impact, indicating that for those two regions, population growth was focused in countries with higher participation rates. In fact, for sub-Saharan Africa, this was actually the dominant effect. Interestingly, Latin America and the Caribbean is the only region that experienced increasing age-specific labour force participation rates during this period.

In 2010–2030, changes in age-specific labour force participation rates are projected to positively affect overall labour force participation rates in every region examined. In fact, for all but South Asia and sub-Saharan Africa, increasing age-specific labour force participation rates will be the primary driver behind increasing overall participation rates. For South Asia and sub-Saharan Africa, the primary driver will be shifts in the age structure, although the projected effects are much more evenly distributed in sub-Saharan Africa than in any other region. In the Arab States, East Asia and the Pacific, and Europe and Central Asia, changes in age-specific labour force participation rates are projected to cause all positive effects, with shifts in the age structure and in country shares of the working-age population tempering these positive effects. Increasing age-specific labour force participation rates are primarily expected to drive increased labour force participation in Latin America and the Caribbean. Shifts in the age structure will have an additional positive effect, while changes in country shares of working-age population will have a slightly negative effect.

Changes in unemployment rates

To this point, we have covered all components of employment other than unemployment rates. Rather than attempting to project unemployment rates out to 2030, we instead treat unemployment in two ways. The first projection of employment needs in 2010–2030 assumes constant unemployment rates at 2010 levels. The second projection assumes the target unemployment rates described in footnote 3, resulting in rates of at or less than 4 percent for

adults and at or less than 8 percent for youth. In 2010, the global unemployment rate was approximately 6.1 percent. Split out for the two age groups, it was roughly 12.9 percent for youth and 4.6 percent for adults. We do not assume different targets based on sex, therefore we assume targets of 4 percent for male and female adults and 8 percent for male and female youths.

Total changes in employment

Using equation (2) to combine the component changes described in the previous sections, we find that in 1990–2010, employment increased by 757 million globally, reflecting approximately 35 percent employment growth. Projecting forward to 2030 and assuming a constant 2010 unemployment rate, we derive the need of 659 million jobs, or roughly 23 percent employment growth. Accounting for the previously described unemployment rate targets, we project an additional need of 75 million jobs, driving the required growth rate from 23 percent to 25 percent. Focusing on the projections that assume our target unemployment rates, the actual number of jobs needed by 2030 is approximately 97 percent of the number created between 1990 and 2010. While the challenge ahead is clearly substantial, and notwithstanding numerous differences between the two time frames (including accelerated automation in the latter), seeking insights from the 1990–2010 experience of job creation is useful.

As far as employment trends by sex are concerned, no substantial differences exist between time periods, but important differences occur between sexes within each period. Due to substantial differences in labour force participation rates, nearly equal changes in male and female populations do not translate into equal changes in the labour force or in employment. While female population growth in 1990–2010 accounted for approximately 50 percent of all population growth, women only accounted for 41 percent of the changes in the labour force and 40 percent of changes in employment. This is due to women having substantially lower labour force participation rates compared with men; in 2010, the participation rates were 55.3 percent for women and 81.4 percent for men in the working-age population. The projected trends for 2010–2030 are nearly identical, deviating only by a few percentage points, and thus this dichotomy between male and female labour force participation and employment is not projected to converge by 2030.

As we saw previously, substantial differences in labour force participation rate changes occurred between youth and adult groups in 1990–2010. Youth participation rates decreased by more than 10 percentage points over this period, which led to decreasing youth employment in spite of an increasing youth population. In 2010–2030, however, the youth labour force participation rate is projected to remain nearly constant. With this and with the youth population still growing in this time frame (albeit at a slower rate than in the prior period), we expect an increasing youth labour force necessitating higher rates of "entry-level' job creation than in the prior period. Coordinated efforts by social security, labour, infrastructure, and education departments could facilitate this labour market transition by providing appropriate training and employment opportunities. .

Compounding this need to create jobs for youth is our unemployment rate target. If we were only concerned with absorbing the growing youth population and maintaining a constant unemployment rate, we would need to create approximately 16 million new jobs. To reduce the unemployment rate to the target level, however, we require an additional 33 million jobs,

bringing the total to roughly 49 million jobs. Strikingly, this 33 million represents nearly 45 percent of the employment needs driven by our target unemployment rates. Considering that the youth labour force was approximately one-fifth the size of the adult labour force in 2010, youth jobs driving close to 45 percent of all unemployment-related growth is remarkable.

Utilizing the decomposition analysis in the section on accounting identities, we find that job creation in 2010–2030 is not quite as intrinsically tied to population growth as in the prior period due to increasing labour force participation rates and decreasing unemployment rates. While population maintains its role as the primary driver behind these changes, labour force participation and unemployment rate changes will play a larger role, accounting for 6.1 percent and 10.1 percent of job creation respectively. This deviates markedly from 1990–2010, when decreasing labour force participation rates actually tempered the task of job creation and decreasing unemployment rates only accounted for approximately 1 percent of the changes.

Examining this decomposition analysis separately for youth and adult workers highlights an interesting example of Simpson's Paradox, a phenomenon in statistics in which a pattern that appears in different subgroups or time periods of data disappears when they are combined (Pearl 2014). Unemployment rates increased for both groups in 1990–2010, which had a negative effect on employment. The overall unemployment rate for the 15–64 working-age population, however, decreased during the same period, which had a positive effect on employment. This inconsistency between the aggregated and disaggregated unemployment rates can be attributed to shifts in the underlying weights of the youth and adult populations. Approximately 31 percent of the working-age population belonged to the 15–24 age group in 1990. By 2010, this proportion had fallen to 27 percent. Thus, even though unemployment rates increased for both groups, a shift occurred from the higher unemployment rate youth group into the lower unemployment rate adult group, leading to a decrease in the overall unemployment rate.

Focusing on regional differences in projected job creation by 2030, more than half of these jobs will need to be created in two regions: sub-Saharan Africa and South Asia. Sub-Saharan Africa in particular faces a substantial challenge, with job needs by 2030 being more than double the number created between 1990 and 2010. For South Asia, the number of jobs that will need to be created by 2030 is roughly 20 percent higher than the number of jobs created in 1990–2010. While these two regions present the most demanding job creation challenges, the Arab States and Europe and Central Asia also face a difficult task in the number of jobs that will need to be created compared with 1990–2010. As these two regions are the smallest of the six analysed, however, the increases do not represent a particularly large proportion of global job creation needs in 2010–2030.

The remaining two regions are actually projected to have lower job creation needs than they did in 1990–2010. The difference is particularly stark in East Asia and the Pacific, where the projected 2010–2030 requirements are roughly 28 percent of the jobs generated between 1990 and 2010. Interestingly, in 1990–2010, only one region (South Asia) had higher population growth than East Asia and the Pacific. In 2010–2030, population growth will drop dramatically for East Asia and the Pacific, while remaining more consistent in South Asia. Thus, two regions that followed a similar path in the first period are projected to diverge sharply in the second

period. Based solely on changes in the working-age population, East Asia and the Pacific appears to have experienced the brunt of absorbing its population boom into employment (Bloom and Williamson 1997), whereas South Asia appears to be in the middle of this task and sub-Saharan Africa will be experiencing it between 2010 and 2030 (and potentially beyond if the 40-year employment growth span witnessed in South Asia is any indication).

Applying the same decomposition analysis from before highlights the differing influence of demographic drivers across regions. In 1990–2010, three regions had decreasing labour force participation rates: East Asia and the Pacific, Europe and Central Asia, and South Asia. This implies that the number of jobs created in these three countries was actually tempered during this period, as a lower proportion of their growing population was entering the labour force. Labour force participation rates had the highest positive impact in Latin America and the Caribbean, accounting for approximately 19 percent of job creation. Job creation in every other region almost solely reflected increasing population, with only a small impact from changes in unemployment rates.

In 2010–2030, the two regions where most jobs need to be created are also those with the strongest population effect. Ninety percent of employment needs in sub-Saharan Africa and 88 percent of employment needs in South Asia are attributable to increasing population. Labour force participation rates are expected to increase in all regions, while unemployment rates need to decrease in all regions to reach the targets. Thus, both of these factors have a positive effect on employment needs in each region and have a greater influence on job creation than in the prior period. This is especially apparent in Europe and Central Asia, where these two factors combined account for 53 percent of job creation. This is the only region where population changes are not expected to account for the bulk of employment growth.

3. Decent work

Definition

The foregoing analysis demonstrates that demographic change is ensuring a continuing job creation challenge. Projected job creation in 2010–2030 remains remarkably close to the number created in 1990–2010—despite decreasing rates of population growth. We face continuing high needs for job creation due to increasing labour force participation rates, shifting age structures, and a desire to reduce the unemployment rate. The challenge, however, is not just the number of jobs that need to be created, but also the quality of those jobs. To that end, we examine the ideal of decent work (ILO 2001).

In 1999, ILO Director General Juan Somavia described decent work as "opportunities for women and men to obtain decent and productive work in conditions of freedom, equity, security and human dignity" (ILO 1999). The United Nations subsequently adopted a set of Millennium Development Goals (MDGs) that ran through 2015, including Target 1.B, to "achieve full and productive employment and decent work for all, including women and young people" (United Nations 2008). A series of Sustainable Development Goals was agreed in 2015, including Goal 8

to “Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all” (United Nations 2015a).

A good starting point for elaborating the definition of decent work lies in the ILO Declaration on Fundamental Principles and Rights at Work (ILO 1998), adopted in 1998, and including the following:

(a) Freedom of association and the effective recognition of the right to collective bargaining,
(b) The elimination of all forms of forced or compulsory labour,
(c) The effective abolition of child labour, and
(d) The elimination of discrimination in respect of employment and occupation.

Jobs that do not abide by these standards cannot be considered decent work, but these standards do not fully capture other aspects of decent work (Anker et al. 2002; Fields 2003). The four indicators reported in the Millennium Development Goals databank (World Bank 2014) encapsulate some of these other aspects: the employment-to-population ratio, the proportion of employed people living below $1 (purchasing power parity or PPP) per day (the poverty ratio), the proportion of own-account and contributing family workers in total employment (vulnerable employment), and the growth rate of gross domestic product (GDP) per person employed (i.e., labour productivity). In addition, we consider total public social expenditure as a percentage of GDP as a potential indicator of decent work.

The availability of these indicators varies widely across countries, and attempting to create a decent work index is beyond the scope of this paper. We have correlated each of these indicators with the stage of development (defined in two ways: human development group from the United Nations Development Programme or UNDP and country income group from the World Bank). Our assumption is that countries on the lower ends of the human development or country income scales are less likely to have well-entrenched traditions of decent work. Table 3 reports the correlation coefficients, and all of these indicators are highly correlated with both human development group and country income group. As such, we are comfortable using these two groups as proxies for whether or not decent work prevails in the countries in question. From the indicators tracked in the MDG databank, one important aspect of decent work clearly has to do with pay. Specifically, the poverty ratio deals with people who are employed but subsist on less than $1 (PPP) per day, and a high poverty ratio can be considered an indicator of indecent work (Fields 2003; ILO 2000). This can be seen in Table 3, where negative correlations between the poverty ratio and our proxies indicate that countries lower on the spectrum of human development or country income group are those where the poverty ratio tends to be high.

While we deal with unemployment in our analysis, we do not deal with the related aspect of underemployment. Underemployment consists of three subcategories: high-skilled workers in low-paying jobs, high-skilled workers in low-skill jobs, or part-time workers who would prefer to be full-time workers (Fields 2003; ILO 2000). Because these three subcategories are not incorporated in unemployment, we have abstracted from them in our analysis. But, insofar as underemployed workers should not be considered as holding decent jobs, the projections in this

paper should be considered conservative as to the number of individuals for whom decent work will need to be generated.

Table 3: Correlation coefficients between decent work indicators and stage of development						
Stage of development scale	**GDP per employed person**	**Total public social expend-iture[7]**	**Poverty ratio**	**Vulnerable employment, total**	**Vulnerable employment, male**	**Vulnerable employment, female**
Human development group	0.7915	0.7043	-0.7458	-0.8136	-0.7896	-0.8147
Country income group	0.8552	0.7345	-0.6401	-0.7939	-0.7753	-0.7854

Source: Authors' work derived from World Bank (2014) and OECD (2017)

[7] The public expenditure figure is taken from the OECDstat database ("Net Total Social Expenditure, in % of GDP"). OECD documentation describes the indicator as covering the following expenditure categories: "Old age, Survivors, Incapacity-related benefits, Health, Family, Active labor market programmes, Unemployment, Housing, and Other social policy" (OECD, 2017).

Table 4: Summary statistics of labour force participation rates and unemployment rates by stage of development (percentages)						
	Labour force participation rates			**Unemployment rates**		
	1990	**2010**	**2030**	**1990**	**2010**	**2030 (targeted)**
Global						
15–64	71.2	68.4	69.4	6.4	6.1	4.0
Human development group						
Very high	69.7	71.4	73.5	7.0	8.3	4.4
High	76.9	72.1	73.1	6.6	5.5	3.9
Medium	64.9	61.8	63.3	5.5	5.5	3.5
Low	68.3	69.1	70.9	6.6	6.4	4.6
Country income group						
High-income	70.8	71.8	73.7	7.8	8.3	4.4
Upper-middle-income	76.3	71.5	72.3	6.3	5.8	3.9
Lower-middle-income	63.5	60.7	62.2	5.7	5.5	3.7
Low-income	77.9	77.4	80.0	5.2	5.3	4.2

Notes:

1) Values represent net effects from beginning to end of period and do not reflect movement in the intervening years.
2) Global estimates represent approximately 99.4 percent of global population due to lack of labour force participation rates for 10 countries: Antigua and Barbuda, Aruba, Curacao, Federated States of Micronesia, Grenada, Kiribati, Mayotte, Seychelles, South Sudan, and State of Palestine.
3) Countries are classified into human development groups based on UNDP's Human Development Index 2013.
4) Countries are classified into country income groups based on the World Bank's country income classifications, as set on 1 July 2014.
6) Source: Authors' work derived from United Nations (2015b) and ILO (2013b)

Table 5: Estimated changes in population, labour force, and employment in 1990–2010 and 2010–2030, by stage of development (millions)							
	Change in population		**Change in labour force**		**Change in employment 1990–2010**	**Change in employment 2010–2030**	
	1990–2010	**2010–2030**	**1990–2010**	**2010–2030**		**Constant 2010 unemployment rate**	**Unemployment rate targets of at or less than 4 percent for adults and at or less than 8 percent for youth**
Global							
15–64	1,300	940	799	695	757	659	734
Human development group							
Very high	107	-3	88	14	75	13	35
High	430	49	248	52	244	51	70
Medium	498	457	281	309	267	296	315
Low	255	432	179	317	168	296	310
Country income group							
High-income	107	-19	84	2	74	2	26
Upper-middle-income	460	107	270	90	259	85	109
Lower-middle-income	544	555	302	369	288	351	371
Low-income	186	297	143	234	135	221	228

Notes:

1) Values represent net effects from beginning to end of period and do not reflect movement in the intervening years.
2) Population numbers are obtained from the UN's *World Population Prospects: The 2015 Revision* (United Nations 2015b) and thus refer to 1 July for each year indicated. Numbers are based on the medium-fertility variant. Note that population growth is fairly sensitive to the variant used.
3) Global estimates represent approximately 99.4 percent of global population due to lack of labour force participation rates for 10 countries: Antigua and Barbuda, Aruba, Curacao, Federated States of Micronesia, Grenada, Kiribati, Mayotte, Seychelles, South Sudan, and State of Palestine.
4) Countries are classified into human development groups based on UNDP's Human Development Index 2013.
5) Countries are classified into country income groups based on the World Bank's country income classifications, as set on 1 July 2014.
7) Source: Authors' work derived from United Nations (2015b) and ILO (2013b).

Key results

Demographic changes have been, and will continue to be, the main drivers behind a growing global challenge to provide decent employment. This challenge is especially concentrated in low-income and low human development countries, where population growth rates are above the world average and traditions of decent work are not well entrenched.

Although low and medium human development (low- and lower-middle-income) countries comprised slightly less than half of the world population in 2010, they are projected to account for more than 80 percent of job creation needs between 2010 and 2030. This concentration of job creation needs is in large part attributable to these countries' disproportionate share of population growth, with more than 90 percent of all population growth projected to occur in low and medium human development (low- and lower-middle-income) countries. General increases in labour force participation, a shift in the age structure from low-participation youth to high-participation adults, and targeted decreases in unemployment rates magnify these population size influences on our employment projections in these countries.

Changes in working-age population

Tables 4 and 5 summarize global changes in population, labour force participation rates, the labour force, unemployment rates, and employment by stage of development. Examining population growth trends by human development and country income groups immediately shows a fairly dramatic split between countries on the low and high end of each scale and a pronounced shift in the distribution of population growth between periods. Among human development groups in 1990–2010, growth concentrated primarily in the lower two groups (medium and low human development). These two experienced growth greater than 50 percent: 56 percent for the medium human development group and 77 percent for the low human development group. Further, in terms of absolute numbers, these two groups combined accounted for 58 percent of total population growth in 1990–2010. The high human development group, however, actually experienced a much larger increase than the low human development group in terms of absolute numbers, with additions of 430 million people compared with 255 million. Combined, the high and medium human development groups accounted for 71 percent of total population growth during this period.

In 2010–2030, population growth will be even more concentrated in medium and low human development countries. During this period, these two groups combined are projected to account for 95 percent of all population growth. In terms of absolute numbers, medium human development countries will add on 92 percent of the additions already experienced, while low human development countries will add 169 percent of the population they added in 1990–2010. By contrast, the working-age population in very high human development countries is actually expected to decrease slightly, by approximately 0.4 percent. High human development countries are only expected to grow by roughly 3 percent, very different from the 33 percent they grew in 1990–2010.

Looking at population growth by country income group paints a similar picture: growth concentrates in the low- and lower-middle-income groups. In 1990–2010, these two groups were

the only ones that underwent population growth greater than 50 percent: 55 percent for lower-middle-income countries and 71 percent for low-income countries. In terms of absolute numbers, however, upper-middle and lower-middle-income countries experienced the largest additions, accounting for 77 percent of total population growth.

Once again, in 2010–2030 population growth will become more concentrated in the lowest country income groups. In absolute numbers, population growth will exceed its 1990–2010 value in both lower-middle- and low-income countries. Lower-middle-income countries can expect to add approximately 102 percent of their 1990–2010 additions, while low-income countries can expect additions of roughly 160 percent of their 1990–2010 additions. Combined, these two groups will account for 91 percent of total population growth in 2010–2030.

Changes in labour force participation rates

Between 1990 and 2010, participation rates increased in very high and low human development countries, while they decreased in high and medium human development countries. The magnitude of the change was greater in the groups that experienced declines, with participation rates falling by 4.8 percentage points in high human development countries and 3.1 percentage points in medium human development countries. Increases in participation rates were 1.7 percentage points in very high human development countries and 0.8 percentage points in low human development countries. Changes in age-specific labour force participation rates predominantly drove participation rate changes in all groups. In low human development countries, shifts in the country shares of working-age populations actually partially offset the positive impact of increasing age-specific labour force participation rates, indicating that population growth was more concentrated in countries with lower participation rates. This holds true for all groups, with the other three experiencing smaller effects. Changes in the age structure positively affected the countries of all human development groups, indicating higher proportions of adult working-age populations in all groups.

Projecting changes in labour force participation rates through 2030, we expect increasing rates in all human development groups. Our decomposition of participation rates shows an interesting difference between the two highest and lowest human development groups. Very high and high human development groups will get the largest positive effect from increasing age-specific labour force participation rates. Simultaneously, these two human development groups expect negative effects from both changes in the age structure and changes in country shares of working-age populations, dampening the positive effect of their increasing age-specific labour force participation rates. Medium and low human development countries, however, can expect the largest positive benefit to come from shifts in their age structures, seeming to indicate large youth cohorts moving into the adult working age over the coming two decades. Increasing age-specific labour force participation rates also have a positive impact, but are not as important as in the other groups. Only low human development countries can expect a positive effect from changes in the country share of working-age population.

Turning to country income groups, only high-income countries experienced increasing labour force participation rates in 1990–2010. Here, increasing age-specific labour force participation rates were the primary drivers of increased labour force participation rates, with a smaller

positive boost from a shifting age structure. Decreasing age-specific labour force participation rates primarily drove decreasing labour force participation rates in the remaining three groups. Each of these three groups, however, also experienced a positive, slightly offsetting effect from shifting age structures, suggesting higher proportions of workers in the adult working-age population.

Projecting participation rates through 2030 reveals a few different trends by country income group. All groups will experience increasing labour force participation rates, with high-, upper-middle, and lower-middle-income countries expected to see increasing age-specific labour force participation rates. This will be the primary driving factor for high- and upper-middle-income countries, where shifting age structures and changes in the country shares of working-age populations partially offset the positive effect. Lower-middle-income countries, however, will receive their largest boost from shifts in their age structure, with a slight offsetting negative effect from changes in the country share of the working-age population. By contrast, increasing labour force participation rates in low-income countries are entirely driven by shifting age-structures, with both other components having a dampening effect.

Total changes in employment

Among human development groups, the distribution of job creation needs splits rather drastically between 2010 and 2030. Mirroring the split in population growth, approximately 85 percent of these jobs are concentrated in countries classified as low or medium human development, based on the Human Development Index. Further, both these groups are projected to face a more difficult task than in the preceding 20-year period. Compared with the number of jobs created between 1990 and 2010, the number required in 2010–2030 will be approximately 18 percent higher in medium human development countries and 85 percent higher in low human development countries. By contrast, very high and high human development countries face easier paths forward, particularly the high human development countries, where the anticipated need for jobs is roughly one-third of the number created between 1990 and 2010.

The decomposition analysis for human development groups provides valuable insights into the composition of job creation needs in each period. For each group, the primary driver of job creation in 1990–2010 was an increasing working-age population. This population effect was partially offset in high and medium human development countries, which experienced decreasing labour force participation rates. Unemployment rates played a more minor role in each group, although they had a larger negative role in very high human development countries.

In 2010–2030, population growth will have a negative effect on employment needs for very high human development countries, where the population is projected to decrease by approximately three million. Population growth remains the largest positive contributor for all other groups, driving more than 85 percent of the need for job creation in medium and low human development countries. Labour force participation rates are projected to have the largest positive effect in very high and high human development countries. Likewise, unemployment rates are projected to decrease to reach our target levels, and the largest positive effect from these will be experienced by very high and high human development countries.

Turning our attention to country income groups, a similar split in job creation needs is evident in 2010–2030, where 82 percent is concentrated in countries classified as either low or low-middle income. By comparison, high-income countries will make up roughly 4 percent of employment needs. Once again, the two classifications facing the greatest challenge are those with the highest projected population growth. Additionally, low- and lower-middle-income countries face a tougher task than they experienced between 1990 and 2010. Lower-middle-income countries will need to generate approximately 29 percent more jobs than in 1990–2010, while low-income countries are faced with the prospect of generating approximately 69 percent more jobs. Both upper-middle- and high-income countries will need to generate less than half of the number generated between 1990 and 2010. Interestingly, upper-middle-income countries experienced the second largest growth in employment in 1990–2010, but low-income countries are projected to overtake that growth between 2010 and 2030 as upper-middle-income country employment needs fall and low-income country employment needs rise.

Revisiting our decomposition analysis, now for country income groups, we find some interesting trends. In 1990–2010, upper-middle-, lower-middle-, and low-income groups had decreasing labour force participation rates, which offset a portion of the population effect. High-income countries, however, experienced increasing labour force participation rates, but simultaneously increasing unemployment rates partially offset these effects. Outside of high-income countries, unemployment rates had a negligible effect in 1990–2010.

Examining trends in 2010–2030, an even greater divergence occurs between high-income and other countries. The working-age population is actually declining in the high-income group, signifying that all employment needs result from changes in labour force participation and unemployment rates. In fact, our target of decreasing unemployment rates seems to be the primary driver, accounting for more than 80 percent of projected job creation needs. Population growth remains the predominant driver of the need for jobs in the other three groups, with upper-middle-income countries having a higher proportion of job creation needs due to labour force participation and unemployment rates than the other two. Population growth is still expected to account for 88 percent of needs in lower-middle-income countries and 96 percent in low-income countries.

4. Behavioural effects of fertility and education on labour force participation

Description of the data

To estimate the behavioural impact of changes in fertility and education on employment through labour force participation rates, we use the data set underlying "Fertility, Female Labor Force Participation, and the Demographic Dividend" by Bloom, Canning, Fink, and Finlay (2009, henceforth BCFF). To tailor this data set specifically to the questions at hand, we also supplement projections out to 2030 with the total fertility rate from *World Population Prospects* (United Nations 2015b) and mean years of education from the International Institute for Applied Systems Analysis (IIASA 2010).

Some important differences exist between our full dataset (henceforth BM) and the BCFF data set. Notably, BCFF only extends through 2000, with coverage of 97 countries, accounting for approximately 80 percent of the global population. Population coverage in BCFF varies considerably across regions. For example, Europe and Central Asia in these data only includes one country that accounts for approximately 30 percent of the population in that region, while South Asia includes six to seven countries depending on the year of analysis and covers between 98–99.9 percent of the total population in the region.

Comparisons between the two data sets can also be drawn based on total fertility rates, labour force participation rates, and mean years of schooling. Global fertility was approximately 2.73 in 2000 (United Nations 2015b). The weighted average of the total fertility rate across the countries included in the BCFF data is 2.64. As for labour force participation rates, BCFF includes data on participation rates for a more limited subset of age groups, specifically 20–44 year-olds in five-year age bands. For analyzing the effect of fertility and education on labour force participation, this does not pose a serious problem because the effects of fertility and education are likely negligible for the 15–19 and 45–64 age groups. The global female labour force participation rate for the 20–44 year-old age group was approximately 64 percent in 2000 (United Nations 2015b). The weighted average of the female labour force participation rate for the 20–44 year-old age group across the countries included in the BCFF data in 2010 is 65 percent. Mean years of schooling for the full set of countries in the Barro-Lee database is approximately 7.19. For the subset of countries included in the BCFF data, mean years of schooling is roughly 7.04. As such, the countries included in these data seem to be a fair representation of the global population as a whole, as they do not substantially deviate from expected values in key variables.

Model

The effects of changes in fertility on employment can be divided into an accounting and a behavioural effect (Bongaarts 1978). The accounting effect is simply that population growth slows due to declining total fertility rates. This decline in population growth leads to fewer entrants to the labour force, therefore easing the task of job creation. The behavioural effect has to do with more women entering the labour force, driving up their labour force participation rates and requiring more jobs to accommodate them (BCCF 2009).

The following analysis relies on regressions used in BCFF where age-specific female labour force participation rates are a function of the total fertility rate, the percentage of the population living in urban areas, physical capital per working-age person, the infant mortality rate, the average years of schooling of men and women, and country and time fixed effects. Abortion legislation is used as an instrument for fertility. The model is run separately for five age-specific labour force participation rates (20–24, 25–29, 30–34, 35–39, and 40–44). The data and results from BCFF show a causal link between the total fertility rate and female labour force participation. As such, we isolate the effect of fertility on labour force participation by using these regressions to project the female labour force participation rate while allowing only the total fertility rate to vary over time. Utilizing the accounting identities presented in equations (1a–d), we trace the effect of changes in fertility on female labour force participation to estimate the job creation needs for women attributable to the concurrent effect of changing fertility.

Our prior analysis of changes in female employment relied on projected labour force participation rates obtained from the ILO, which differ from what this model projects. The BCFF model isolates the effect of changes in fertility and projects higher female labour force participation rates. The ILO projections rely on a two-step procedure of mechanic projections and judgemental adjustments (ILO 2010; ILO 2013a). Two mechanic projections are calculated: a constant scenario that is used as a reference point and a logistic trend scenario that combines projections from four variations of their basic equation. Two of these variations include two variables that are of particular interest in comparison with our analysis: the share of children (0–14) in the total population and the share of older persons (60-plus) in the total population. Additionally, contrary to the analyses undertaken in the ensuing sections, the ILO projections do not explicitly account for projected changes in educational attainment. To the extent that mean years of schooling are expected to increase over time, the ILO projections may fall short of what our model predicts.

Based on this approach, our estimates of female labour force participation may be higher than the ILO estimates for several reasons. Because the ILO takes account of the share of older persons, the effect of fertility may be offset to a certain extent. Perhaps as populations age and mortality increases, the burden on women of caring for family members shifts from children to older persons. Even when having to care for fewer children, having to care for longer-lived parents could conceivably offset the beneficial effect of lower fertility on female labour force participation. Another possibility is that the inclusion of models that do not account for these dependency rates in their combination may somewhat depress the effect of fertility on labour force participation. As the goal of our analysis is to isolate the separate impacts of fertility and education, we are not concerned that we have obtained different labour force participation projections from the ILO, as any factors that may offset the effect of fertility should not change the isolated effect.

Table 6: Isolating the impact of changes in fertility or education on employment during 2010–2030					
	Change in fertility/education	**Change in labour force participation rate (percentage points)**	**Change in employment (assuming constant labour force participation rates at 2010 levels, in millions)**	**Change in employment (using BCFF-projected labour force participation rates, in millions)**	**Change in employment (isolated effect due to change in fertility or education, in millions)**
Effect of fertility on female labour force participation rate	-0.25	3.6	232	323	91
Effect of education on female labour force participation rate					
Male effect	0.94	-2.3	234	177	-58
Female effect	1.39	2.7	234	302	68
Net effect	--	0.4	234	245	11
Effect of education on male labour force participation rate					
Male effect	0.94	0.2	379	384	5
Female effect	1.39	-0.9	379	356	-24
Net effect	--	-0.7	379	361	-18

Notes:

1) Projections of labour force participation rates are based on BCFF data and model. They are then applied to the BM population data to obtain an estimate of employment needs for the global population.
2) Projections of changes in labour force participation rates are based on the 20–44 age group. We assume negligible effects of fertility and education on the 15–19 and 45–64 groups and apply these changes to the 15–64 age group as a whole.
3) Net effects of education are simply the sum of male and female effects.
4) Source: Authors' work derived from United Nations (2015b), ILO (2013b), World Bank (2014), Barro-Lee Educational Attainment Dataset (2012), and Bloom, Canning, Fink, and Finlay (2009)

Fertility effect

Table 6 traces the impact of changes in total fertility rates and education on employment, through labour force participation rates, in 2010–2030. We isolate the effects of fertility and education by taking the difference between projections of employment that use constant labour force participation rates at 2010 levels and projections that use labour force participation rates as projected through the BCFF model. Due to the scope of the data described previously, projections from the BCFF model are applied to population values from the BM data set. This provides estimates of fertility and education effects extended to a global scale as opposed to the subset of countries included in the BCFF. Further, we assume negligible effects of fertility and education in the 15–19 and 45–64 age groups, allowing us to apply these projections to the 15–64 working-age population.

Turning our attention first to the impact of fertility, declining global total fertility rates suggest increasing female labour force participation rates. In 2010–2030, the global total fertility rate is projected to decrease by approximately 0.25, resulting in a projected increase in female labour force participation of 3.6 percentage points. Assuming constant labour force participation rates at 2010 levels, approximately 232 million women globally would need jobs. Allowing age-specific labour force participation rates to change as a result of decreasing fertility as projected in the BCFF model, we find an additional 91 million women requiring jobs. This reflects roughly a 28-percent increase in the number of women seeking employment due solely to changes in fertility. By contrast, the ILO projections estimate an increase of only 0.6 percentage points in female labour force participation between 2010 and 2030. As touched upon previously, because we are calculating the isolated change in labour force participation due to changes in fertility, several factors could explain the sizable difference between the values discussed here and those reported in Table 2.

Education effect

Before discussing our estimates of the effect of education on employment, one caveat deserves to be mentioned. Our education analysis uses different periods for the male and female regressions. The female regression utilizes available labour force participation rates from 1960–2010, while the male regression only utilizes labour force participation rates from 1990–2010. The BCFF data set was designed with the goal of estimating the effect of fertility on female labour force participation rates and thus did not include male rates. As such, we supplemented the data with male rates from the BM data. Values prior to 1990, however, were not included in that data set and were not fully available in the ILOSTAT database (ILO 2013b) used to extract labour force participation rates. With this in mind, we have examined the male regressions to ensure that the coefficients on the two education measures behave in a reasonable manner, and we are confident that the values reported are reliable estimates reflective of the underlying trend.

Examining net effects of education on labour force participation rates tends to mask the underlying pattern of offsetting effects from changes in male and female education. Increasing male education negatively impacts on female labour force participation and positively impacts on male labour force participation. Meanwhile, increasing female education negatively impacts on male labour force participation and positively impacts on female labour force participation.

These findings are consistent with the story that male earnings have an income effect on female labour supply, thus lowering female work incentives. Additionally, there is a substitution effect of female earnings on female labour supply, increasing female work incentives (Goldin 1995). The substitution effect dominates the income effect, and thus the net effect of changing education on female labour force participation is positive. The same trend holds true for male labour force participation, resulting in a negative net effect of education on male participation rates and employment.

In 2010–2030, mean years of schooling are projected to increase by 0.94 for men and 1.39 for women. The increase in male education corresponds to a projected decrease in the female labour force participation rate of 2.3 percentage points and a projected increase in the male labour force participation rate of 0.2 percentage points. The increase in female education corresponds to a projected increase in the female labour force participation rate of 2.7 percentage points and a projected decrease in the male labour force participation rate of 0.9 percentage points. Summing the individual effects of education, we find net effects of a 0.4 percentage point increase in female labour force participation and a 0.7 percentage point decrease in male labour force participation.

Interestingly, the female labour force participation rate seems to be more sensitive to changes in sex-specific education than the male rate. The net effects dilute this sensitivity, however, and leave us with a result in which male labour force participation appears to be more sensitive to changes in education. Tracing these net effects, the isolated effect of education on employment for women is an addition of 11 million jobs. For men, changes in education reduce the number of jobs needed by approximately 18 million. Thus, changes in education increase the number of jobs needed for women by approximately 5 percent, while reducing the number of jobs needed for men by approximately 5 percent. This further highlights the importance of looking separately at sex-specific effects of education, as even the overall effect of education on labour force participation is offsetting.

5. Automation and Digitalization[8]

The trend of rapidly increasing automation and digitalization poses an intensifying challenge to job creation (Ford 2015; Acemoglu and Restrepo 2017a; Prettner and Strulik 2017). In the automotive industry, industrial robots already substitute for assembly line workers on a large scale. The mining industry relies on self-driving trucks that only need to stop once a day for refueling (*The Economist* 2017; *The New York Times* 2017). 3D printers are increasingly common in the production of customized products that previously required intensive labour input (Abeliansky et al. 2015). This is particularly the case with respect to tailor-made medical products, such as hearing aids and implants, and spare parts that are only needed infrequently or in small quantities. However from a technical perspective, printing entire houses is even feasible

[8] This article uses the term digitalization to refer to the process of using digital technologies and data to replace or transform business processes, with the intention of increasing revenue streams, reducing costs, or improving services. Automation is the process of making a task or procedure executable without human assistance. There is substantial overlap between these terms and both have the potential to net positive or negative effects on job creation.

(*The Guardian* 2015). The prospect of self-driving cars and lorries might be particularly worrying from the perspective of job creation, considering the large share of the workforce employed in driving related occupations worldwide.

While it is tempting to conclude that investing in higher education is the best strategy for workers to cope with technological progress, physically demanding and repetitive jobs are not the only ones that are susceptible to automation. Over the past decade, machine learning has progressed such that automated algorithms are already widely used for writing newsflashes, reports, and even novels; searching for precedential cases in law firms; diagnosing diseases; and even—strikingly—discovering laws of nature (Schmidt and Lipson 2009; National Science Foundation 2009; Ford 2015). One of the consequences of automation and digitalization is a profound change in employment relationships; as a result, workers are often not hired on a permanent basis but on demand. The catchphrase "gig economy" has been coined for this new type of labor (ILO 2016; Todolí-Signes 2017), which has in many cases left both high- and low-skilled workers without a reliable and permanent income source.

These described changes pose a strong headwind for the creation of decent jobs as outlined previously and begs the question of how many jobs could potentially be replaced by automation and digitalization in the near future. To address this question, Frey and Osborne (2017) use a Gaussian process classifier to estimate the probability of automation for 702 different occupations in the United States. Their results show that 47 percent of all U.S. workers are subject to a high risk of their jobs being automated over the next two decades. While these findings have elicited strong responses from the media and policymakers, Arntz et al. (2017) suggest that these concerns may be overblown, highlighting the heterogeneous nature of tasks within many occupations. Taking into account that many seemingly automatable jobs also include tasks for which machines are not well suited, such as problem solving or influencing decision making, they determine that the fraction of jobs that are truly at a high risk of automation over the next two decades might be substantially lower than Frey and Osborne (2017) predict. According to Arntz et al.'s (2017) calculations, 9 percent of jobs are at risk.

Furthermore, while automation is technically feasible for tasks performed by a range of workers this does not necessarily imply that all of these worker will actually be replaced by robots, 3D printers, or other automated devices. The decision to utilize automation technologies or workers is ultimately based on economic considerations. Consequently, our calculations of the additional jobs necessary to offset the impact of automation are based on projections of the stock of available industrial robots. The number of operative industrial robots worldwide was negligible in the 1970s, increased to 1.06 million units in 2010, and is projected to rise to 3.05 million units by 2020 according to the data and projections of the International Federation of Robotics (2017). When extrapolating their 14 percent underlying trend growth rate to 2030, we get a worldwide operative stock of industrial robots of around 11.3 million units in the year 2030. This implies an increase of 10.26 million units from 2010 to 2030.[9]

[9] The Boston Consulting Group (2015) projects between 4 million (baseline) and 6 million (high-variant) industrial robots by 2025. Our projection for the year 2025 is well within this range.

Using Acemoglu and Restrepo's (2017a, p. 4) recent findings that one industrial robot could directly replace 5.6 to 6.2 manufacturing workers in the United States, the increase in the stock of industrial robots between 2010 and 2030 is equivalent to an additional labor supply of 57 to 64 million workers. Consequently, the number of jobs that need to be created between 2010 and 2030 to reach the targeted unemployment rates would rise to 791–798 million.

However, large uncertainties surround the projections and estimates of how many jobs industrial robots could replace. First, anticipated outcomes vary widely for different countries under consideration. For example, Dauth et al. (2017) apply the same methodology as Acemoglu and Restrepo (2017a) to Germany and find that one additional industrial robot only replaces two manufacturing workers. They explain this finding with the labor relations in Germany that resulted in unions and work councils accepting lower wages in exchange for job security. Considering the findings for Germany as a baseline scenario, the world economy would need to add 755 million jobs between 2010 and 2030 to reach targeted unemployment rates. Second, some general equilibrium effects are not taken into account when only computing the direct job losses due to industrial robots. For example, the robot construction and maintenance industry is likely to expand employment if more robots are used and the prices of the goods produced by robots are likely to decrease, which in turn leads to real income gains that can be spent on other goods and services (Acemoglu and Restrepo 2017a). Indeed, studies find that the replacement of manufacturing jobs by robots often goes hand in hand with the creation of jobs in the service sector (Autor and Dorn 2013; Dauth et al. 2017). These general-equilibrium effects do not factor in to our job creation needs projections, which refer to the total number of jobs that need to be created, including those that will emerge as a consequence of automation.

However, two issues deserve mention in the interest of putting our estimates of the effects of automation in perspective. First, industrial robots are predominantly installed in highly developed countries because these countries have a high level of economic activity and therefore a strong demand for labor. At the same time, these countries are subject to aging and declining workforce growth, such that labor is scarce. This implies high wages and a strong incentive to automate (Abeliansky and Prettner 2017; Acemoglu and Restrepo 2017b). Consequently, automation will disproportionately impact labor markets in highly developed countries. Second, industrial robots are only one category of automated devices capable of replacing workers. As mentioned previously, 3D printers, diagnostic tools based on machine learning, algorithms that write reports and newsflashes, and robots in the service sector are all likely to have an effect on future employment as well. As such, our projections of the number of additional jobs needed to compensate for automation should be considered conservative.

6. Conclusion

A transitory issue

While the world faces a formidable task of job creation through 2030, reason for optimism exists regarding the challenge post-2030. Job creation requirements between 2010 and 2030 predominantly reflect population growth in the prior two decades, which was the largest period

of population growth in history. Because of these lags in the effect of fertility, currently decreasing fertility and population growth rates imply that this is a transitory issue rather than a permanent one.

In 1990–2010, the working-age population grew faster than the labour force did. Between 2010 and 2030, however, the reverse is projected. The differences in youth and adult population growth partially explain this reversal in growth rates. In 2010–2030, the youth population is projected to grow by 5 percent, a considerably lower growth rate than the adult population growth rate of 27 percent. This is due primarily to decreasing fertility and population growth leading to low rates of replacement in the youth working-age population. The adult working-age population will continue to grow at a much higher rate due to large youth cohorts moving into the adult population in the near future.

Impact of today's job creation on tomorrow's labour force

While we have focused primarily on the effect demographics have on decent work, it is also worth noting that increases in decent work would likely have an impact on future demographics. As was touched upon previously, creating decent work involves both absorbing new members of the labour force into employment and restructuring existing work to ensure it fits the standards of decency. As more of the population is employed in decent work, fertility is likely to decrease further. This is especially true if a high proportion of women become decently employed, as they will have less incentive to leave the workforce due to the quality of the jobs they hold. As fertility declines, children more easily attain higher levels of education because fewer children allows a higher investment in human capital per child (Lee and Mason 2010a). As the average level of education increases, the quality of workers increases, requiring further enhancement of the type of jobs available. This effect would have a considerable lag though, perhaps a generation long, as it depends on the investment of benefits earned through decent work into enhancing the human capital of the children of those employed in decent work.

Impact on social security systems

In their current form, the solvency of most social security systems depends on the ratio of contributors to dependents in an economy. If the growth in dependents substantially outpaces that of contributors, social security systems are bound to face serious challenges in terms of their long-term financial sustainability. Given the demographic trends unfolding globally and the increasing headwinds of automation and digitalization, a failure to create the jobs needed through 2030 would undermine efforts to ensure vital social protection floors.

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