Popul Res Policy Rev (2017) 36:441–466
DOI 10.1007/s11113-016-9423-z

The Future Labor Force of an Aging Taiwan: The Importance of Education and Female Labor Supply

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Received: 26 January 2016 / Accepted: 30 November 2016 / Published online: 17 December 2016

Abstract This study uses multi-state cohort component projections and detailed vital statistics data to project the future Taiwanese population by age, sex, and education up to 2050. These are the first education-specific population projections for Taiwan, and they reveal how young highly educated cohorts during the next decades will replace older cohorts with lower levels of educational attainment. The results of the population projections enter our estimation of the future composition of the Taiwanese labor force. Incorporating education as an extra dimension in labor force projections allows us to make inferences about the quality of future labor supply in a rapidly aging Taiwan and the leverage of expanding economic activity across the life course, particularly of women. At present, women's economic activity above age 25 in Taiwan is significantly lower than men's and also much lower than women's in Western developed nations. Some of the expected adverse economic consequences of population aging can likely be alleviated by having a more educated and consequently more productive labor force. The overall results and conclusions of our study, though based on the Taiwanese context, apply to other Asian economies with rapidly aging populations and currently comparatively low levels of female labor force participation as well.

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Keywords Labor force projections · Female labor force participation · Education projections · Population aging · Taiwan

Introduction

Population aging is a pressing demographic issue in many advanced Asian economies, and Taiwan is no exception. Industrialization that took place in the 1970s and 1980s has been accompanied by a rapidly progressing pace of population aging in Taiwan. The period total fertility rate of Taiwan used to be as high as seven children in 1951, and it first dropped below the replacement level of 2.1 in 1984 (Ministry of the Interior 1975–2013). As Taiwan made the transition to a post-industrial society in the late 1990s, population aging has been further accelerated by a dramatic fertility decline and substantial improvement in life expectancy at birth. Period total fertility declined further from 1.68 in 2000 to a record-low of 0.90 children in 2010, with a slight rebound to 1.07 as of 2013 (Ministry of the Interior 1975–2013). Meanwhile, life expectancy at birth in 1950 used to be 53.1 and 55.7 years for men and women, respectively. Within a span of six decades, it has greatly improved to 76.4 years for men and 82.5 years for women in 2010 (Department of Household Registration 2013).

Population aging does not necessarily entail negative macro-economic consequences, given that adequate policies concerning labor markets, capital markets, retirement, and health systems are in place (Bloom et al. 2015). In particular, there is an increasing body of research that looks at how a smaller but more productive labor force might be able to make up for (some of) the expected decline in economic output that is projected for countries with aging populations and which finds clear positive effects of increased investment in education (Fougere et al. 2009; Ludwig et al. 2012). For example, Börsch-Supan (2003) showed for the case of Germany that increases in capital intensity alone will not be enough to compensate for a reduced number of economically active people, and that strengthening education and training will be crucial for human capital formation (Börsch-Supan 2003). Similarly, Lee and Mason (2010) demonstrate the positive economic effect of replacing larger, less productive cohorts with smaller, more productive ones (Lee and Mason 2010). Given the projected continued shift in educational attainment of the Taiwanese population toward higher degrees, it is reasonable to expect similar effects in Taiwan.

To gauge how improvements in education will change the education composition of the future labor supply, population and labor force projections are needed. Official population projections of Taiwan have been done by the National Development Council (i.e., the former Council for Economic Planning and Development), and education has never been considered in the projection procedures (Council for Economic Planning and Development 2010; National Development Council 2014). Knowing not only changes in the size but also the potential skill level of the population of working age is crucial, yet the incorporation of education as an important aspect of population projections is a rather recent practice (Lutz et al. 1998). Key demographic indicators such as fertility and mortality in general exhibit strong social gradients in

education: The better-educated bear fewer children and have lower mortality risk than their less-educated peers. Incorporating education into population and labor projections offers researchers and policy makers a more fine-tuned developmental portrait of population structure in the long run. In fact, education as a dimension of population projections has been included in global population projections (for 195 countries) by the Wittgenstein Centre for Demography and Global Human Capital (Lutz et al. 2014). In addition, labor force projections that take into account education as an extra dimension have been done in previous research for 26 EU countries and for China and India (Loichinger 2015a, b).

This study will provide population and labor force projections by education up to 2050 with the aim to unravel the future population and labor structure of Taiwan. The results will not only allow us to assess the future labor pool in terms of age and size but at the same time offer insights into the future educational composition of the workforce. In particular, the impact of incorporating more women into the labor market can be more precisely assessed, which bears important policy implications. First, as a growing share of young Taiwanese women have received tertiary education (e.g., 67% of women aged 25–29 in 2012 had at least junior college education[1]) and are gainfully employed, they can potentially offset part of the downward pressure on economic growth due to labor shortage from shrinking cohort sizes with higher productivity. Increasing productivity is crucial for a society that has to prepare itself for a steep rise in old-age dependency (measured as the ratio of the population age 65 and above to the population age 15–64): from 14.6 in 2010 to 68.1 in 2050 (Department of Household Registration 2013; National Development Council 2014). Second, an accompanying benefit could be a rise in fertility, since developed nations where women are most integrated into the labor force are also those with near-replacement-level fertility (Billari and Kohler 2004; Brewster and Rindfuss 2000).[2] A good example is Sweden. With regard to fertility level, female labor participation, and participation of the elderly, Sweden tops the chart in Europe. Hence, a Swedish scenario will be utilized in the labor force projection to demonstrate the potential labor force structure in 2050 Taiwan should the working population be optimally incorporated into the labor market.

The three questions that this paper addresses are as follows: (1) What is the educational composition of the Taiwanese population in 2050, given past and current trends in educational attainment? (2) Building upon these education estimates of the Taiwanese population in 2050, what is the projected labor supply by educational level based on selected labor participation scenarios? (3) In particular,

[1] Junior college education in Taiwan refers to a type of tertiary education that emphasizes applied and vocational education. There used to be three types of junior colleges. The 2- and 4-year junior colleges recruit vocational high school graduates; the 3-year junior colleges accept high school graduates, and finally the 5-year junior colleges admit junior high school graduates. Upon finishing any of these junior college education programs, students are considered having completed college education and will be eligible to apply for a master's program should they wish to continue their education. Many of these junior colleges reformed their curricula and have been upgraded to be "university of (science and) technology" since the late 1990s as a result of a recent wave of educational reform.

[2] The relationship between female employment and fertility can be more complex at the micro-level and can depend on variations in country-specific policies (Gauthier 2007; Matysiak and Vignoli 2008).

what is the estimated impact of high-skilled female labor supply on the total workforce in 2050?

This case study of Taiwan will shed light on the future development of labor force in other East Asian societies with a similar demographic profile of low fertility, low female labor participation, fast educational expansion, and rapid population aging problems, such as Japan, South Korea, Singapore, and Hong Kong. Also outside of the Asian context, past and ongoing changes in educational attainment, particularly of women, will raise similar questions to the ones we answer in this paper. This will be especially so in countries which are faced with labor shortages due to aging populations.

The sections below will first offer an overview of population projections and their policy implications for an aging Taiwan. Next, the association between improved education and female labor force participation, as well as barriers to fuller employment among women, will be discussed. The data and methods will be described, followed by results for the population and the labor force projections. A discussion of our findings concludes the paper.

Population Aging and Labor Supply in Taiwan

Over a span of four decades, Taiwan has aged rapidly. The median age used to be 21.3 in 1975, yet it has increased to 37.3 in 2010. As shown in Fig. 1, the wide-based population pyramid of rapid population growth observed in 1970 has transformed into a spindle-shaped pyramid in 2010. The substantial growth in age 60+ population has been accompanied by a considerable decline in the number of children under age 15. Within the next 15–20 years, the median age of Taiwan is estimated to rise above 50 (Council for Economic Planning and Development 2010). Such dramatic demographic transformations are with consequences, including the thinning of kinship sizes, the impact on taxation and income support, changes in intergenerational transfer patterns, the sustainability of pension and medical care programs, as well as the decline in labor supply.

Population structure is of prime importance to development. The age structure implies distributions of age-specific behaviors that are closely linked to distinct economic outcomes. Prime-age adults provide labor and save, while the young and old need investments in education and health care, respectively. Changing population shares at different ages thus influence the economic performance and burden of a country and subsequently determine the prospect for growth or decline. The impressive economic growth observed among the *Asian Tigers* offers some of the most telling evidence for reaping the benefits of the "demographic dividend" in the 1970s and 1980s (Bloom et al. 2003). During this period, the baby-boom generations began to enter the working ages, which rapidly increased the total capacity for economic production in these industrializing nations. Such changes in the demographic structure spurred development and growth, which further pushed down family sizes. Fertility decline further freed women from childrearing and increased total female labor supply that also contributed to a boosting economy

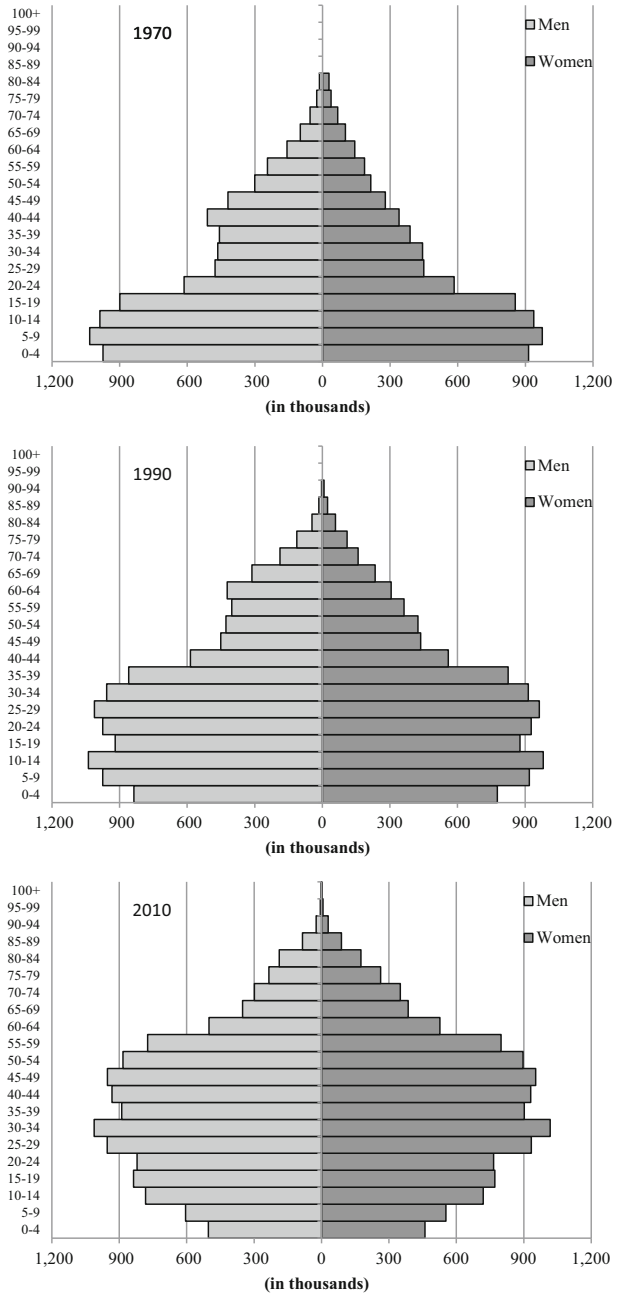


Fig. 1 Population change in Taiwan, 1970–2010
Source: data acquired from the Statistical Yearbook of the Republic of China (1970, 1990, 2010), published by the Department of Household Registration, Ministry of the Interior, Taiwan

(Bloom et al. 2009). Yet, this period of having a growing working-age population is soon coming to an end in Taiwan.

While discussions about the consequences and implications of an aging society have largely focused on increases of medical expenses for an expanding old-age population as well as a shortage of labor supply, changes in the educational composition in a fast-aging Taiwan is absent from scholarly literature or the public attention. Empirical research and policy recommendations have often focused on incorporating more middle- and mature-aged men and women into the labor market (Tsay 2003; Wang et al. 2009), while some have suggested extending the official retirement age, importing more foreign labors, or implementing pension reforms to alleviate dependency burdens (Chen 2005; Hseuh 2003; Tsay 2003).

Still, policies aimed at progressively raising women's overall labor force participation, as a crucial measure for the "Abenomics" proposed by the Japanese prime minister Shinzo Abe (Fifield 2014), have not been put forth in Taiwan. Despite the average educational attainment of young cohorts of Taiwanese women having improved considerably over the past decades, the current level of labor force participation of women in Taiwan leaves room for further improvement at almost all age-groups. Women's labor force participation patterns by age in many western developed countries tend to resemble more and more those observed for men, particularly when comparing higher educated men and women. In Taiwan, age patterns of female labor force participation come nowhere close to those of their male counterparts and are also much lower than those observed among women in many developed societies. While it has been documented that part-time work among women and the elderly make up a sizable share of the high labor force participation rates in many developed countries (OECD 2016), the percentage of part-time work for women in Taiwan has been quite minimal when compared to international standards. Take 2013 for example, part-time female labors constitute 16.2% of the total female labor force in South Korea, 36.2% in Japan, 16.7% in the U.S., 26.2% in Canada, 22.5% in France, 37.9% in Germany, 18.3% in Sweden, and 28.8% in Norway, yet it is only 4.8% in Taiwan (DGBAS 2015; OECD 2016).

Education and Female Labor Force Participation in Taiwan

Since the 1970s, educational expansion has taken place along with industrialization in Taiwan, which has led to large differences in the educational compositions across birth cohorts. In 1975, less than one in ten (9.7%) young adults aged 25–29 received tertiary education. By 2010, more than half (58%) of the 25–29-year-olds had at least a junior college degree, whereas three-fourths of the over 60-year-olds had less than high school education (Ministry of the Interior 1975–2013).[3] Along with this

[3] Education system in Taiwan is characterized by 6 years of elementary education, followed by 3 years of junior high school education. Junior high school graduates can choose to proceed to regular high schools (academic track) or vocational ones (both are 3 years). Another option is to enter 5-year vocational school, which will grant a junior college degree. High school graduates who proceed to tertiary have the options of entering regular 4-year universities/colleges or receiving a junior college degree in either a 2-year or a 3-year college (which is equivalent to the associate degree in the United States).

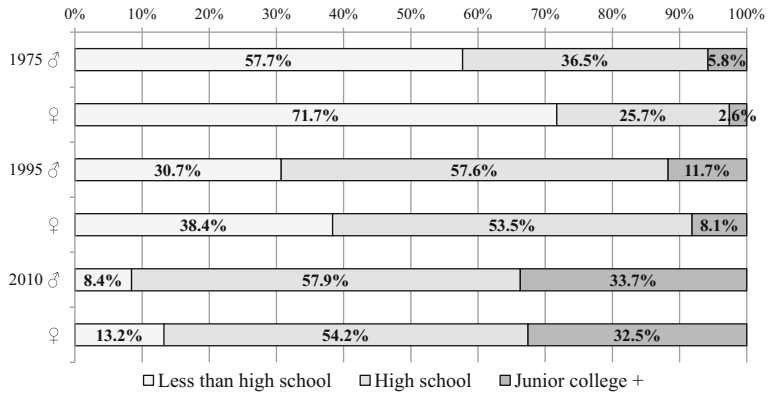
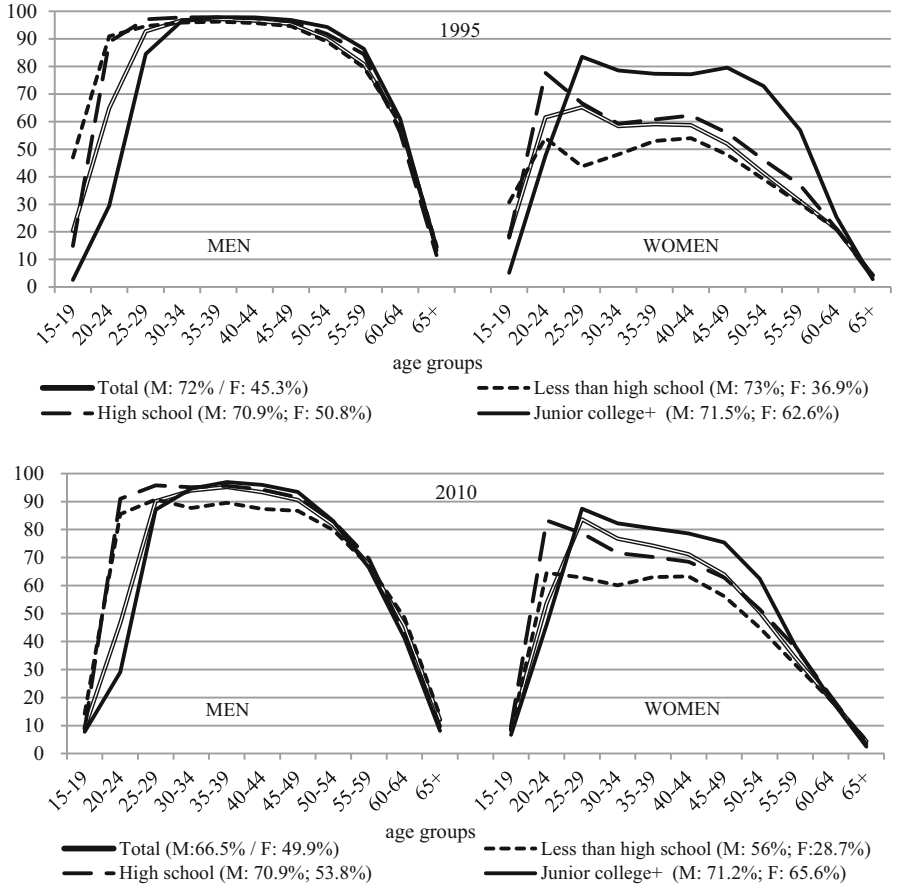


Fig. 2 Education composition of the 15–64-year-old population by sex in Taiwan, 1975, 1995, and 2010 *Source*: data acquired from the Statistical Yearbook of the Republic of China (1975, 1995, 2010), published by the Department of Household Registration, Ministry of the Interior, Taiwan

rapid advancement in education, the proportion of women among all college students rose from 21% in 1960 to 36% in 1970 and further to 50% in 2010 (Ministry of Education 2012). These changes along cohorts lead to noticeable compositional changes in Taiwan's working-age population. As shown in Fig. 2, the proportions of men and women with tertiary education (i.e., junior college and above)[4] among the 15–64-year-old population have increased and converged substantially from 1975 to 2010 (33.7% men and 32.5% women in 2010, compared to 5.7% and 2.6% in 1975, respectively). At the same time, the share of men and women with less than high school education has been reduced to about 10% during this 35-year period, which is in stark contrast to that observed in 1975 where the vast majority of the adult population had not completed high school. This educational expansion has positioned women in favorable spots to compete in the labor market during Taiwan's economic booms in the 1970s and 1980s.

Since the late 1990s, a considerable number of employment opportunities are knowledge- and service-based that often require more than a high school degree. Rising women's education has been accompanied by a significant growth in female labor force participation rates between 1987 and 2010: from 56 to 84% between ages 25 and 29 and from 55 to 77% between ages 30 and 34 (DGBAS 1987–2010). The female graphs of Fig. 3 in both the upper and lower panels illustrate the fact that from 1995 to 2010 a sizable growth in female labor force participation rates at nearly all ages in all educational levels took place, except for an earlier withdrawal from the labor market due to early retirement for better-educated women. At the same time, education differentials in participation have decreased, but overall levels of female labor force participation are still much lower than those of men in both years.

[4] The labor force—synonymous to the (economically) active population and labor supply—comprises both, employed and unemployed persons. The labor force participation rate is defined as (employed + unemployed)/(population) × 100%. It can be calculated for individual age-groups or aggregated across the adult population.



Note: The earliest year when age-specific labor force participation rates by education are available is 1995.

Fig. 3 Age patterns of labor force participation by education for men (M) and women (F) in 1995 and 2010. (The aggregate participation rates given in the legend refer to ages 15+.)
Source: labor force participation data acquired from "Time-series Data Bank, Pre-2012," published by the Directorate General of Budget, Accounting, and Statistics, Executive Yuan, Taiwan (http://www.dgbas.gov.tw/ct.asp?xItem=18843&ctNode=4943)

Improvements in women's overall education do not necessarily imply an increase in labor force participation. State and industry-specific regulations regarding the recruitment, promotion, and earnings of women are structural factors that shape the level of labor force participation among women. Past research has shown that aside from the sociodemographic characteristics of women, the broader institutional context explains a considerable amount of between-country variations in women's employment patterns (Nieuwenhuis et al. 2012; Pettit and Hook 2005). Although the average educational level of women in Taiwan is among one of the highest in Asia, women's labor force participation rate (LFPR) for ages 15 and above in 2012 (50.2%) is only slightly higher than Japan's and South Korea's and lags behind

several neighboring societies like Hong Kong, Singapore, Thailand, China, and Vietnam, as well as many developed western countries like the UK, France, Germany, and USA (Ministry of Labor 2013; Ogus and Hedrick-Wong 2013). The following sections will first address the factors that are associated with women's rising labor force participation in Taiwan, and then the deterrents that have slowed down further improvements in women's labor market attachment.

Contextualizing Rising Female Labor Force Attachment in Taiwan

The costs and eligibility requirements of achievement tests are two institutional arrangements in the Taiwanese educational system that facilitate women's access to higher education, which significantly contributes to past increases in labor force participation among women. This explains why the overall level of labor force attachment among women is higher in Taiwan than in Japan, although industrialization and economic development started much earlier in Japan (Yu 2009). During the post-war period, the employment patterns of Taiwanese women were quite similar to their counterparts in Japan. Most women worked in factories and farms that require low skills, and they withdrew from the labor market after marriage to bear and to rear children. Over a course of four decades, Taiwanese women have had markedly different employment trajectories and occupational attainment when compared to their Japanese peers. The divergence is mainly driven by two key processes (Yu 2009).

First of all, the export-oriented industrialization gave rise to the dominance of small- and medium-sized enterprises (SME) in the Taiwanese economy during the post-war era. Frequent labor shortage in the SMEs led to incorporating more women into the labor market. The relatively informal work climate in these small-scale businesses also facilitated the balance of work and family for married women. In companies where higher-skilled laborers were needed, demand for well-educated female workers has been even greater, largely due to a shortage of high-skilled male workers.[5] With a growing economy and rising female educational attainment, female workers have increasingly been able to stay in the labor force longer throughout working ages. The educational system that shapes the supply of highly qualified workers and minimizes educational inequality by sex is another critical factor that gives rise to women's favorable employment outcomes and rising status attainment in contemporary Taiwan (Yu 2009).

The second key factor that contributes to women's rising education and competiveness in the labor market can be traced back to the institutional settings of high school education: the majority of the best academic-track high schools in Taiwan are sex-segregated public institutions. Consequently, girls are competing with their same-sex peers, not against boys who in general score higher in high school entrance exams (Yu 2009), which ensures a comparable number of female students can enter the top high schools. So how does a sex-segregated high school

[5] Until the rapid expansion of higher education in the late 1990s, such a shortage results from the fact that only about 8% of each birth cohort received a college degree (5% men and 3% women). A substantial share of male students was channeled into the vocational education system after junior high schools to meet the demand of technicians during the process of economic development.

system minimize gender inequalities in educational opportunities for higher education? The crucial factors are (1) the low-cost, nationwide joint entrance exam system facilitates transition to tertiary education and avoid the problem of parental preferential investment in sons over daughters when educational costs are high; (2) given that admission rates to elite universities are comparable among boys' and girls' top high schools, once boys and girls are enrolled in high schools, they are basically competing in a merit-based system. As a result, even though the total percentage of female college students never exceeded 40% prior to 1986, the share of female students in the elite National Taiwan University has never fallen below 40% from the mid-1960s to the turn of the new millennium (Yu 2009).

Why are Female Labor Force Participation Rates not Higher?

The total LFPR for Taiwanese women is lower than in many developed societies largely due to the phenomenon of "late entry and early exit." That is, women in Taiwan start working at an older age than their counterparts in other nations, which is due to extended education and family financial support for children in schools. Women in Taiwan also tend to drop out of the workforce or retire earlier due to various reasons such as marriage, childbirth, and generous pension plans for public servants and teachers. Hence, there is still plenty of room to incorporate more women into the labor market.

In Taiwan, women still shoulder the bulk of care work for children and the elderly in their families, despite the tremendous progress they have made outside their homes in education and paid employment. A critical reason why labor force participation rates of women are often lower than those of men lies in employment disruptions in the course of family formation events, both marriage and childbearing. The fact that only a part of these women reenter the labor market and many of them pay a penalty for job interruption by taking up part-time or lower-ranked positions has made the opportunity costs of family formation, particularly childbearing, quite pricey for women. Deep-rooted cultural beliefs on traditional gender-norms have formed a glass ceiling to equal employment patterns for both sexes.

In a recent round of the Survey of Women's Marriage, Fertility and Employment collected in 2010, about 26% of married female workers age 15–64 left their jobs because of marriage and another 16% due to childbirth (Chang 2013). About 45% of those who left work for marriage and 55% of those who left due to childbirth returned to the labor market. Re-entry into the labor market for these women usually took six to seven years on average, although this period has been reduced for the more recent cohorts (Chien 2004). In general, women with more education tend to have lower likelihood of leaving their jobs for family formation reasons (Chang 2006). Another recent study reveals that employment rates of married mothers with preschool-aged children in Taiwan have grown considerably over the past few decades, from 34% in 1983 to 62% in 2006 (Jao and Li 2012). This is congruent with patterns observed in other OECD countries with a large service sector, where an increasing trend toward more labor force participation among mothers is reported from 1975 to 1999 (Nieuwenhuis et al. 2012). Based on the progress women have

made in advancing to higher education and because more education is linked to stronger labor force attachment, it is reasonable to expect that the labor supply of highly qualified women will continue to grow. We aim to evaluate its scope of growth and impact with education-specific population and labor force projections for Taiwan up to the year 2050.

Data and Methods

Given that Taiwan is not a member country of the United Nations, many demographic reports and projections the United Nations release do not explicitly include Taiwan. To obtain our base population and input for our projection assumptions, we compiled data from Taiwanese government websites and publications regarding past and present developments of population, fertility, mortality and migration, as well as labor force participation.

Population Projections

We projected the population for Taiwan from 2010 to 2050 using the multi-state cohort component method (Land and Rogers 1982). This allowed us to incorporate differentials in demographic parameters not only by age (0–4, 5–9, …, 95–99, 100+) and sex, but additionally by highest level of educational attainment. We used four education categories: those with less than high school education (equivalent to ISCED 0/1/2), those with a high school degree (ISCED 3), and two groups for those with a tertiary education (ISCED 5/6), i.e., junior college and college/beyond college.[6] The data sources, data modifications, and assumptions for the parameters required for the projections are described below.

Fertility

Taiwanese women with less than a high school degree had a period Total Fertility Rate (TFR) of 1.23 in 2010, whereas women with a college degree had a TFR of 0.87 (Ministry of the Interior 1975–2013). Using time-series data for age-specific fertility rates (ASFR) by education, we adopted the 5-year limited extrapolation method proposed in Myrskylä and colleagues' recent work to project the development of age-specific fertility rates forward (Myrskylä et al. 2013). Based on the slope between 2005 and 2010, we extrapolated education-specific ASFRs 10 years forward and then froze the resulting values until the end of the projection period. This entails a slight increase in overall TFR during the projection period, from 0.96 in 2010–2015 to 1.12 in 2045–2050. The sex ratio at birth has been declining from 110.7 in 2004 to 107.1 in 2014 (Ministry of the Interior 1947–2015). We assumed a value of 107 for 2015–2020 and kept it constant at 106 during the subsequent periods.

[6] There is not a category that is comparable to ISCED 4 (post-secondary, non-tertiary education) in Taiwan. Thus, ISCED 4 is not part of the current study.

Mortality

In terms of mortality, age-specific mortality rates by education for men and women in 2010 were calculated using death counts and year-end population by age, sex, and education requested from the Department of Household Registration, Ministry of the Interior. These rates served as input for future mortality rates that were modified to incorporate expected increases in life expectancy: we followed the life-expectancy assumptions of the Council for Economic Planning and Development (2010) which means male life expectancy at birth will reach 82.45 years in 2050 and women are projected to live to age 88.55. Since men as well as and women show distinctly different levels when comparing their education-specific life expectancies, we did take these education differentials into account. For example, in 2010, the difference in life expectancy between men with less than a high school degree and men with a college degree was almost 11 years. The respective difference for women was half of that value (authors' own education- and sex-specific death rates and life table calculations based on education-specific death counts). We gradually reduced these differentials between 2010 and 2050 to the values presented in KC and colleagues' (KC et al. 2010): those with less than high school education have a life expectancy that is 3 years lower compared to those with completed high school, whereas persons with tertiary education live on average 3 years longer than high school graduates. There are no assumed differences anymore between men and women in these differentials in 2050.

Migration

When it comes to migration, Taiwan is a unique case where the volume of female net migration is many times higher than that of their male counterpart, which is mainly due to marriage migration (Wang and Chang 2002; Yang and Lu 2010). The number of immigrants and emigrants by age and sex were requested from the Department of Household Registration, Ministry of the Interior. Between 2009 and 2010, the net migration volume for men was 745 persons, whereas it was 21,116 for women. We do not have data on the education structure of in- and out-migrants and hence distributed the number of net migrants equally between the 4 education categories, and kept this distribution and volume of net migration constant during the whole projection period. Given the low volume of net migration, compared to the population size of Taiwan, our assumptions about the characteristics of male and female net migrants will not influence our projection results in a significant way.

Education Transitions

As stated earlier, the four categories for the highest educational attainment are less than high school education, high school, junior college, and college and above. Age-specific transition probabilities between educational levels for men and women were calculated separately, using the population counts by age (5-year age-groups) and education, for the time period 1975–2010. Our assumptions about the future development of education transitions were based on the analysis of trends during

this period for six transition possibilities: from less than high school to completed high school, for 15–19- and 20–24-year-olds, respectively; for completed high school to junior college, for 20–24- and 25–29-year-olds, respectively; and for completed high school to college and above, for 20–24- and 25–29-year-olds, respectively. We used synthetic cohorts to obtain these transition trends, i.e., we calculated (period) transition rates for each year we had data for and extrapolated each of the six mentioned transitions probabilities forward until 2050.[7]

Labor Force Projections

Labor force participation does not enter our population projections as a multi-state dimension. Instead, we projected age-, sex- and education-specific rates separately and applied them in a second step to the population projections described above. Population data for the two highest education categories, i.e., junior college and college/beyond college, were collapsed in one group representing all those with tertiary education (junior college+). Figure contains differences in economic activity by education level for Taiwanese men and women in 2010, aggregated for ages 15+. In 2010, overall labor force participation for men is 66.5% and for women 49.9%. The absolute and relative gap in labor participation rates between men and women with a university degree (ISCED 5/6) is smallest, and largest for those who have at most completed junior high school (ISCED 0/1/2).

Next, we calculated four scenarios of future labor force participation: a constant approach, a cohort scenario, an equalization scenario, and a Swedish scenario. In each but the constant scenario, we vary the overall level of participation particularly of women and persons above age 50, and by doing so also implicitly change the educational differentials in participation rates. The assumptions of each scenario are discussed in the next section. We applied labor force participation rates for 5-year age-groups, ranging from ages 15–19 to 75+.[8]

[7] To estimate the effect of our assumptions on the outcome of the projections, we ran an additional seven scenarios where we varied the assumptions about Taiwan's future fertility, mortality, migration, and education transitions. This showed that reasonable changes in the assumptions for fertility, mortality, and migration did not change the overall picture at all. Concerning educational attainment, our assumptions about the transition into university might actually turn out to be on the conservative side, since we assume a leveling off of the transition trend from high school into college/university among 25–29-year-olds once two-thirds in this age-group make this transition (projected to happen in 2020). If we let the past trend continue so that the transition probability into college/university eventually reaches 100% within this age-group (projected for 2030 for women and 2035 for men), the educational upgrading of the future Taiwanese labor force might be even stronger than what we estimate. (Detailed results of these alternative scenarios are available from the authors upon request).

[8] The last age-group that sex- and education-specific labor force participation data were available for is ages 65+. This causes problems when doing projections, since the age composition within this age-group will change drastically during the projection period, shifting toward higher age-groups. Hence, we estimated participation rates for 2005 and 2010 for two further closed age-groups (65–69 and 70–74) by assuming participation at age 75 and higher is 0 and interpolating linearly in between ages 60–64 and 75+. We applied the education gradient observed for 65+ for all ages above 65 and adjusted the interpolated values with an adjustment factor by minimizing the difference between the labor force size 65+ when applying the rates for the whole open-ended age-group and the labor force size obtained when applying individual rates for 65–69 and 70–74.

The constant scenario freezes age-, sex-, and education-specific participation rates at their observed levels in 2010 (as shown in Fig. 3) and keeps them constant for the whole projection period until 2050. This means that any change in the size and composition of the future labor force is purely driven by changes in the population size and structure.

The age schedules of labor force participation by education for both sexes in 2010 emphasize the substantial gender disparities in economic activity. To see the effect that complete convergence in participation would have, *the equalization scenario* assumes that by 2050 female participation rates will reach male participation levels that were observed in 2010. Linear interpolation is used to obtain age- and education-specific participation rates for the years between 2010 and 2050. Male participation in this scenario does not change and is equivalent to the constant scenario.

The cohort scenario incorporates a dynamic cohort approach. The developments of participation rates along cohort lines are analyzed and future developments of participation are calculated applying entry rates into the labor force and exit rates from the labor force (Carone 2005; Loichinger 2015b; Schrier 2010). In our case, the entry and exit rates observed between 2005 and 2010 are kept constant. In doing so, increases in women's participation observed during this period are projected to continue as younger cohorts gradually replace older cohorts, so female participation is significantly higher in 2050 than in 2010. As the younger generations of women come of age in subsequent cohorts, more of them take part in the labor force and contribute to economic activity than their older counterparts. Cohort developments for men are minor and therefore we see little change in comparison to the constant scenario.

In the Swedish scenario, we assumed that the age-, sex-, and education-specific participation rates that were observed in Sweden in 2013 will be attained in Taiwan by 2050, for men as well as women. Sweden is the leading country in Europe when it comes to female participation and participation of the elderly and for this reason our choice of a benchmark country. In 2013, overall female participation (ages 15–74) in Sweden was 68.7%, and male participation was 74.3%. Particularly the value for women is significantly higher than what is observed in Taiwan (53.7% in 2010, cf. Table 2). Participation of older Swedes (ages 60–64) is at particularly high levels, 64.4 and 73.7% for women and men, respectively. Linear interpolation was used for the participation rates between 2010 and 2050. This is the only scenario where male participation is assumed to change in addition to female participation, since the constant and the equalization scenario by construction do not affect males' participation rates and recent cohort changes were minimal for men.

Table 1 gives an overview of age- and sex-specific participation rates in 2010 and for each scenario in 2050. These are the participation rates, across education levels, which were calculated retrospectively. This is also the reason why the constant scenario does not show identical values in 2010 and 2050: since the educational composition of the population changes between 2010 and 2050, the application of education-specific labor force participation rates entails a change in participation rates across education categories.

Whereas male participation rates are very similar across the different scenarios (with the exception of significantly higher participation rates under the Swedish

Table 1 Labor force participation rates by age, sex, and participation scenario, 2010 and 2050

	2010	2050			
		Constant scenario	Cohort scenario	Equalization scenario	Swedish scenario
Men					
15–19	12.7	12.7	12.7	12.7	37.3
20–24	73.6	72.5	73.1	72.5	74.1
25–29	90.4	88.9	90.1	88.9	89.6
30–34	93.8	94.6	95.9	94.6	96.1
35–39	95.2	96.5	96.7	96.5	97.8
40–44	93.3	95.3	95.2	95.3	97.3
45–49	90.5	92.8	92.0	92.8	96.8
50–54	81.7	82.8	81.0	82.8	94.0
55–59	67.6	67.3	64.7	67.3	92.7
60–64	45.6	42.5	40.7	42.5	77.0
65–69	28.7	22.2	20.7	22.2	28.0
70–74	14.8	11.2	11.7	11.2	15.2
Women					
15–19	8.6	8.6	8.6	12.7	43.6
20–24	68.6	72.0	72.2	72.4	72.5
25–29	82.4	85.6	86.2	88.5	86.0
30–34	76.3	79.7	83.3	94.4	89.7
35–39	74.1	77.9	82.2	96.3	93.1
40–44	70.9	76.0	82.2	95.1	93.7
45–49	63.6	72.2	82.3	92.7	93.1
50–54	50.2	59.4	70.3	82.7	92.7
55–59	34.2	37.7	50.0	67.2	87.1
60–64	19.3	19.7	31.1	42.4	70.8
65–69	10.8	7.2	14.4	22.0	17.8
70–74	4.4	2.9	6.8	11.0	8.6

Source: labor force participation data for 2010 come from "Time-series Data Bank, Pre-2012," Directorate General of Budget, Accounting, and Statistics, Executive Yuan, Taiwan (http://www.dgbas.gov.tw/ct.asp?xItem=18843&ctNode=4943)

scenario), female participation rates increase gradually from constant to cohort, equalization, and Swedish scenario.

Results

Combining observed and projected data, the educational composition of the Taiwanese population shifts from one where the majority—73% of men and 81% of women—did not possess a high school degree in 1980 to one where more than half of the adult population will have obtained a tertiary degree in 2050 (see Fig. 4).

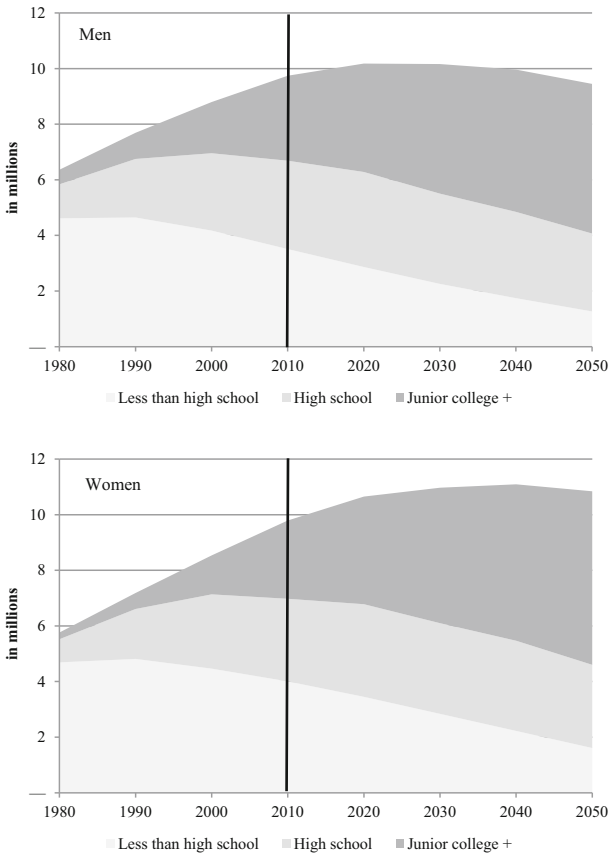


Fig. 4 Changes in population composition of education by sex and education, 1980–2050. Men (*top*) and women (*bottom*)
Source: data for years 1975–2010 are acquired from the Statistical Yearbook of the Republic of China, published by the Department of Household Registration, Ministry of the Interior, Taiwan. For years after 2010, the data for the educational composition are projections done by the authors

As shown in Fig. 5, population aging is expected to progress in a rapid pace over the next 40 years. The population pyramid will transform from a spindle-shaped to a mushroom-shaped pyramid—one with a small share of the population below age 15 (9%, down from 16% in 2010) and a sizable proportion of senior citizens beyond age 65 (36.7%, up from 10.7% in 2010). Total population size is projected to peak in 2030 at 24.0 million people, up from 23.2 million in 2010 and declining to 22.4 million in 2050. In terms of educational composition, individuals with tertiary education will dominate the adult population ages 25 and above if past trends of educational expansion continue. In 2010, about 35% of men and 31% of women ages 25 and older received tertiary education. By 2050, the share of tertiary-educated men and women will increase to 61% for both sexes, according to the projection results. In particular, the absolute number of women above age 25 who received tertiary education will exceed that of men within each five-year age-group,

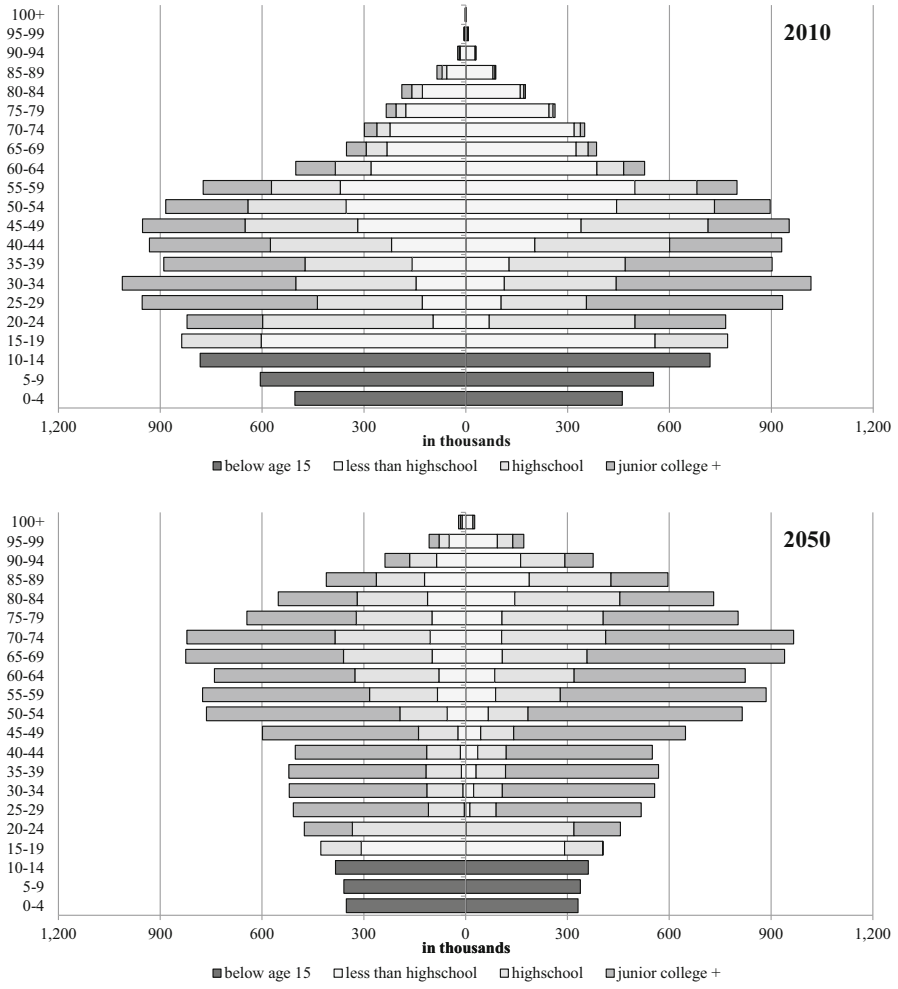


Fig. 5 Taiwanese population by age, sex, and education in 2010 (observed) and 2050 (projected)
Source: data for year 2010 come from the Statistical Yearbook of the Republic of China, published by the Department of Household Registration, Ministry of the Interior, Taiwan

resulting in 6.1 million of tertiary-educated women versus 5.2 million of tertiary-educated men. This is a tremendous growth in Taiwan's high-skilled population from 2.5 million women and 2.7 million men observed in 2010, respectively.

In the next step, we applied the aforementioned four labor force participation scenarios to the projected population structure for years 2010–2050. As shown in Fig. 6, irrespective of the chosen scenario, total labor supply will reach its peak by 2020, followed by a constant decline during the next three decades with varying speed across the projection scenarios. The Swedish scenario will result in the most optimistic outcome of 10.9 million laborers by 2050, compared to 11.7 million in 2010, followed by the equalization scenario that yields 9.6 million laborers. The

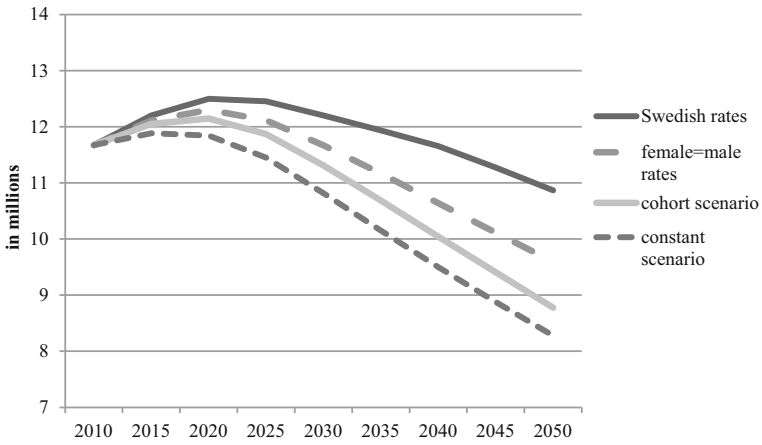


Fig. 6 Total size of labor force by projection scenario, 2010–2050
Source: authors' own calculations

constant and the cohort scenario are expected to result in 8.3 and 8.8 million workers in 2050, respectively. This shows that the current state of cohort progression in female labor force participation patterns will fail to offer enough labor supply in an aging society to offset the decline due to changes in the demographic composition. More progressive measures in increasing female labor force participation at all ages, such as those observed in the equalization and Swedish scenarios, are imperatively necessary. Our results are in line with what has previously been illustrated by Tsay (2003), where 8 scenarios of future labor force participation were presented and projected between 7.9 and 10.3 million workers in 2050.

A closer look at the labor projection results based on different scenarios reveals considerable differences in aggregate labor force participation for the population aged 15–74. Table 2 shows that all scenarios will result in a significantly smaller share of working-age men in the labor force than what was observed in 2010, except under the Swedish scenario. In contrast, the equalization and the Swedish scenario predict a noticeably larger proportion of women in the labor force in 2050 than in 2010, and the reduction is only 2% points for the cohort scenario.

When it comes to the educational composition of the future labor force, its structure will be quite different compared to 2010, given a continuation of past education trends: There will be hardly any workers with less than a high school degree, and the share of those with a high school degree as their highest level of educational attainment is projected to drop from over a third in 2010 to a fourth in 2050 (cf. Table 2). At the same time, the share of the labor force with a tertiary degree is projected to increase from 39% to around 70% between 2010 and 2050, which represents a relative increase of more than 75%. Overall, the share of non-tertiary workers will be tremendously downsized from 60% of the entire labor force in 2010 to 30% by 2050. The fact that the educational profiles of the projected labor force vary only minimally by labor projection scenarios indicates that educational

Table 2 Aggregate labor force participation rate (ages 15–74) and labor force composition (%) by education (ages 15+), by sex and participation scenario

	2010	2050			
		Constant scenario	Cohort scenario	Equalization scenario	Swedish scenario
Labor force participation rate					
Men	73.0	61.8	61.2	61.8	72.3
Women	53.7	44.9	51.6	61.1	67.1
Labor force composition (%)					
Total					
Less than high school	24.9	5.9	6.3	6.9	6.2
High school	36.8	24.9	25.1	25.0	24.1
Junior college+	38.3	69.2	68.6	68.1	69.7
Women					
Less than high school	22.3	5.6	7.0	7.6	6.5
High school	36.3	21.6	22.8	22.7	21.5
Junior college+	41.4	72.8	70.3	69.7	71.9
Men					
Less than high school	26.8	6.2	5.6	6.2	5.9
High school	37.2	27.5	27.3	27.5	26.7
Junior college+	36.0	66.3	67.1	66.3	67.4

Source: labor force participation data for 2010 come from "Time-series Data Bank, Pre-2012," Directorate General of Budget, Accounting, and Statistics, Executive Yuan, Taiwan (http://www.dgbas.gov.tw/ct.asp?xItem=18843&ctNode=4943); data for 2050: authors' own calculations

differences in labor force participation patterns only play a limited role in shaping the composition of the future labor pool. What matters is the educational attainment structure of the adult population.

Table 2 also illustrates the difference between men and women when it comes to the educational composition of the labor force: even though a significantly lower share of women than men was in the labor force in 2010, female workers were already then on average higher educated than male workers—41% of tertiary-educated women vs. 36% of men with this education level. This discrepancy is projected to persist during the next decades, regardless of the labor projection scenarios used.

To further evaluate the impact of changing size and skill compositions of the labor force, the actual sizes of projected workforce by sex and education under the four scenarios are shown in Table 3. According to the population projection presented earlier, there will be a 22% decrease in the total population ages 15–69 from roughly 18 to 14 millions in between 2010 and 2050 (results not shown). The first panel in Table 3 shows that unless more progressive measures to increase female labor force participation are taken (e.g., the equalization or Swedish scenarios), the scope of labor shrinkage will be larger and faster than the decrease in the total population. For instance, the constant and cohort scenarios both show a

Table 3 Total size and change in size of the labor force by sex, education, and scenario, 2010 and 2050

Labor force size	2010	2050			
		Constant scenario	Cohort scenario	Equalization scenario	Swedish scenario
Total (in 1000s)	11,671	8279	8777	9593	10,867
Change 2010–2050		−29%	−25%	−18%	−7%
Women (in 1000s)	4953	3655	4199	4969	5462
Change 2010–2050		−26%	−15%	0%	10%
Men (in 1000s)	6718	4624	4578	4624	5405
Change 2010–2050		−31%	−32%	−31%	−20%
Females	Labor force size (in 1,000s)				
Less than high school	1106	205	292	378	357
High school	1797	789	956	1129	1176
Junior college+	2049	2661	2951	3462	3928
Males	Labor force size (in 1,000s)				
Less than high school	1800	285	256	285	320
High school	2497	1271	1251	1271	1443
Junior college+	2422	3067	3071	3067	3643
Females	Change 2010–2050				
Less than high school	1106	−81%	−74%	−66%	−68%
High school	1797	−56%	−47%	−37%	−35%
Junior college+	2049	30%	44%	69%	92%
Males	Change 2010–2050				
Less than high school	1800	−84%	−86%	−84%	−82%
High school	2497	−49%	−50%	−49%	−42%
Junior college+	2422	27%	27%	27%	50%

Source: see Table 3

decrease of 29% and 25% in total work force by 2050. In contrast, the Swedish scenario indicates a fall of only 7%, and it will result in the slowest shrinkage of blue-collar workers and the fastest growth in high-skilled workers for both sexes (see bottom two panels in Table 3). The growth in tertiary-educated women of all workers is particularly fast (from 18% to 33–36%) when compared to growth in men with a similar skill level (from 21% to 32–37%) between 2010 and 2050. In particular, of the extra 2.1 millions of workers predicted under the Swedish scenario, when compared to the cohort scenario, about 60% of them are female laborers (1.3 millions) and three-quarters of these women are tertiary-educated. This clearly demonstrates that taking progressive measures to incorporate more women into the labor force can substantially compensate for the labor force shrinkage caused by population decline and aging.

Eventually, what matters is not only size and the educational composition of the labor force alone, but also the proportion of the overall population that is economically active: the fact that the population of Taiwan is projected to decline

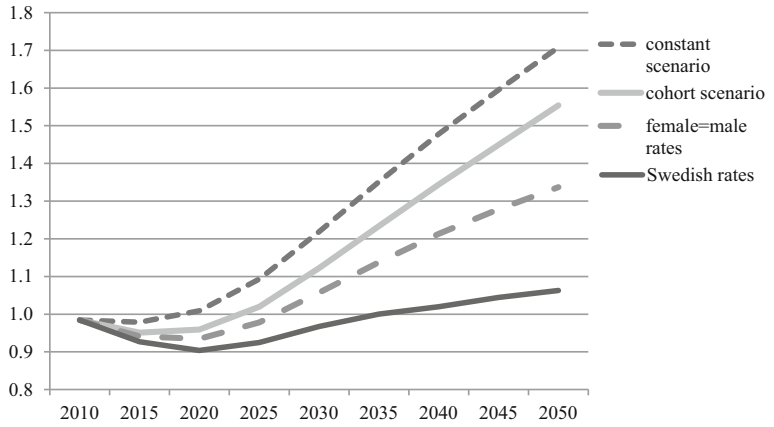


Fig. 7 Economic dependency ratio, 2010 to 2050, by participation scenario
Note: Economic dependency is defined as the ratio between the inactive and the active population, i.e., (total population − labor force)/(labor force)
Source: authors' own calculations

after 2030 has to be taken into account. This can be done by looking at economic dependency, which relates the number of persons that are not economically active to those that are. This value is about 1 for Taiwan in 2010. Figure 7 illustrates the development of economic dependency according to the four participation scenarios and reveals that economic dependency is actually not increasing until around 2020 even under the constant participation scenario. The other three scenarios would even entail an initial moderate decline. Only the Swedish scenario, however, would show an increase that would lead to a level not much above current dependency, namely 1.06, during the next four decades.

Discussion and Conclusion

This paper provides population and labor force projections for Taiwan, taking compositional changes in education between 2010 and 2050 into account. Results from the population projections indicate that total population size is projected to peak in 2030 at 24.0 million people and decline to 22.4 million in 2050. Given a continuation of past trends in educational attainment, individuals with tertiary education will dominate the adult population ages 25 and above in 2050. In 2010, about 35% of men and 31% of women ages 25 and older received tertiary education. By 2050, the share of tertiary-educated men and women will increase to 61% for both sexes. In particular, the total number of tertiary-educated women will exceed that of similarly educated men in all age-groups above age 25.

As far as the labor projections are concerned, all participation scenarios forecast a shrinking labor force by 2050, with the Swedish scenario representing the most optimistic outcome. This scenario yields an extra 2.1 million workers, compared to the cohort scenario, and about 60% of them are female laborers (1.3 millions) and

three-quarters of these women are tertiary-educated. When broken down by sex, the total supply of male workers will decrease in all projection scenarios, and only the Swedish scenario forecasts an about equal aggregate male labor force participation rate for ages 15–74 in 2050 than in 2010. For women, the current pace of cohort progression in rising female labor force participation patterns will fail to substantially expand the total supply of working women in the absence of more proactive measures to incorporate more female laborers, as it would be the case under the assumptions of the equalization and Swedish scenario. A shift toward the Swedish age and sex patterns of labor force participation, potentially achievable through changes toward more liberal gender-roles and labor policy reforms, would certainly change the landscape of labor supply in the decades to come. This would not only mean increased female participation but also increases in participation of the elderly of both genders. The fact that such levels of participation are presently possible in Sweden is a promising indicator that this could also be achieved during the next four decades in Taiwan. This would allow economic dependency to only increase marginally compared to the present situation.

Public opinions on the gender division of labor in Taiwan have become more liberal, as manifested in a declining approval of the male-breadwinner and female-housekeeper model across all age and sex groups between 1991 and 2011 (authors' own calculations using the Taiwan Social Change Survey). At the same time, the share of female workers in part-time jobs is considerably lower in Taiwan than in many other developed societies. Both of these phenomena should prompt the government to make structural changes by adopting more flexible policies to encourage higher labor participation among women. More women- and family-friendly policies, as well as extending the current statutory retirement age, are imperative for preventing the labor force from shrinking to a non-sustainable size. A firm policy change to incorporate more women into the labor force at all ages could provide a substantial pool of laborers for a rapidly aging society that faces a pressing labor shortage issue without foreseeable replacement migration policies. In aging societies, policy makers might try to remedy the speed of aging by providing incentives to boost fertility. However, the effect of increasing fertility on labor supply is moderate and can only be seen as a long-term option, since it takes time before even immediate increases in fertility would lead to an increase in the number of persons of working age. It can at best be seen as an additional measure, not the principal policy, for counteracting the inevitable trend toward a shrinking labor force. In the end, whether Taiwan aims for the Swedish level of labor force participation rates or continues with its path of cohort progression in labor force attachment will lead to a difference of more than 2 million workers by 2050—among which more than two-thirds will be tertiary-educated.

Despite the foreseeable shrinkage of total labor supply, one notable trait of the future Taiwanese labor force lies in its skill level. The projection results show that about 70% of the entire workforce in 2050 will be tertiary-educated in all scenarios. While these high-skilled workers will be roughly evenly split between the two sexes, the equalization and the Swedish scenarios forecast slightly more female than male tertiary-educated workers by 2050. Given that the most educated tend to have much higher rates of labor force participation and stay in the labor force longer than

the less educated (Myrskylä et al. 2013), the gains in productivity that can be expected along with this shift in the workforce's skill level will be able to take some pressure from the consequences of a shrinking labor force. It also has to be kept in mind that due to cohort replacement, future workers between ages 50 and 74 will have very different education levels and occupations compared to its current peers, potentially allowing them to work until higher ages with more ease. Of course, this will only be possible if labor demand for older workers keeps up with their supply.

In addition, the tremendous downsizing of non-tertiary-educated workers from 60% of the entire labor force in 2010 to 30% by 2050 should be evaluated with caution. Given that many manual and service jobs have gradually been replaced by robots and automated machine services, future improvements in computer-assisted programs and artificial intelligence can alleviate the pressure of labor shortage. The long-feared potential deficit in labor supply brought by population aging may not be as problematic if a sufficient share of the gap can be filled by automation. However, not all manual work is replaceable by robots and a shortage of laborers has already plagued the manufacturing and construction industries in Taiwan in recent years. It is clear that striking a balance between maintaining a decent supply of blue-collar workers and expanding the usage of robotic systems will be critical to long-term development purposes. According to the projection results, scenarios where women are more progressively incorporated in the labor market will lead to not only a larger work force but also slower decline in low-skilled workers.

Concerning the size of the future labor pool, our projections arrive at similar results as those provided by Tsay (2003) about a decade ago. As a crucial extension, however, the findings here further reveal important information about the educational composition of the future labor force: The future workers of Taiwan will predominantly be college-educated, high-skilled men, and women. As always with projections, particularly for a period of four decades, there are several sources of uncertainties. First, it is not a given that educational attainment continues to follow the observed trend during the last 35 years. However, evidence from other countries in the area—notably South Korea and Singapore (Lutz et al. 2014)—supports the assumption of projected further attainment increases in higher education also in Taiwan. The largest uncertainty with population projections comes through migration, and if the currently low level of net migration increased significantly in the future, this could lead to a different population size and age-structure. However, this would require a significant increase in the volume of net migration, and the most recent trends (since 2010) actually showed a decline in net migration. Also, our assumptions about the future development of labor force participation only represent four possible developments out of a spectrum of possible assumptions. Still, the constant and the Swedish scenario likely represent the lower and the upper bound of what can be expected and span the outcome range of labor supply. Finally, while replacement migration has been proposed and implemented as an alternative measure to cope with severe aging problems in many developed societies, it has never been considered nor will it likely be proposed as a policy to supplement the shortage of newborns resulting from local Taiwanese women's sustained low fertility over the past few decades. The total volume of in-migration to Taiwan has been relatively small when compared to many migrant-accepting countries. Of all the migrants to Taiwan, only a share of them

stayed and became citizens of Taiwan, particularly if they are marriage migrants. The majority of migrant workers returned to their home countries after their contracts with local employers ended. Hence, although migration often enters the projection process as a critical factor, in the case of Taiwan, it is unlikely that new patterns of migration will substantially alter the projection results.

All this being said, women's labor attachment is inevitably and intricately intertwined with education, marriage, and childbearing. With more women in the labor force, it can further bring about policies that facilitate childbearing and the balance of work and family, which can potentially lead to a shift in fertility toward higher levels in many contemporary low-fertility social contexts (Ahn and Mira 2002; Uunk et al. 2005). In addition, the increasing share of tertiary-educated women will certainly have implications not only for the labor market but also the marriage market (Blossfeld 2009; Kashyap et al. 2015). For instance, recent research found that in quite a few developed nations as well as a few Asian societies, women's higher educational attainment is associated with more, rather than fewer, marriages (Cheng 2014; Fukuda 2013; Goldstein and Kenney 2001; Heard 2011; Ono 2003; Schwartz and Mare 2005). Moreover, a recent study by Kashyap et al. (2015) has investigated how social change (measured by female advancement in education) affects demographic outcomes in rapidly developing India. The authors' projections show that with substantial improvement in women's educational attainment, a continued shift toward higher proportions of educationally homogamous marriages will dramatically decrease the percentages of well-educated women who are never married by age 50 (Kashyap et al. 2015). Consequently, while women's gain in educational attainment initially may create a marriage squeeze that makes them disadvantaged in the marriage market, this squeeze will become less severe over time if social values and preferences for educational homogamy continue to spread. More marriages will likely lead to rising fertility, since a major reason for the extremely low levels of fertility in Asia is caused by declines in marriage rates and the close link between marriage and fertility. If an equilibrium of high levels of female socioeconomic status and family formation can be attained, the implications of population aging would be assessed differently as it is done nowadays.

Acknowledgements Funding was provided by the Ministry of Science and Technology, Taiwan (Grant No. 105-2410-H-001-043-MY2) and the "Wittgenstein Award" of the Austrian Science Fund (FWF): Z171-G11. The authors thank the editor and the reviewers for helpful comments on an earlier version of this paper. We also thank Fen-Chieh Felice Wu for excellent research assistance.

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