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Who Gains from the Demographic Dividend? Forecasting Income by Age

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Abstract

Changes in the population age structure are known to influence the total income per person, but little is known about whether the changes are equally shared across the population or are concentrated on particular age groups and/or birth cohorts. The answer to this question has potentially important implications for income inequality, for human capital investment, and for fertility decision-making. We propose a new model of intergenerational transfers which distinguishes between the effects of changes in population structure and the effects of changes in family age structure. Using age-specific data from annual income and expenditure surveys of Taiwan between 1978 and 1998, we show that changes in age structure have had a very favorable effect on Taiwan's income growth. The gains are not equally shared by all age groups, however. Children and young adults have benefited the most, while the elderly have benefited the least. The population and family age structures have independent effects on per capita income; the effect of the population age structure is most important. Generational differences in per capita income are closely related to intergenerational differences in earnings, suggesting only a weak form of altruism. Finally, we predict that, on average, population aging will adversely influence per capita income growth in Taiwan in the coming decades.

Keywords

demographic dividend; intergenerational transfers; income forecasts

1. Introduction

Changes in the population age structure have led to growth in the per capita income being substantially higher than the growth in output per worker in the US (Cutler, Poterba, Sheiner, Summers, & Akerlof, 1990), East Asia (Bloom & Williamson, 1998; Mason, 2001b), Egypt (Bloom & Canning, 2003), and in many other countries around the world (Kelley & Schmidt, 2001; Mason & Lee, 2004). This has largely occurred because changes in age structure lead to a divergence between population growth and growth of the working age population. Unfortunately, the phenomenon is beginning to work in reverse in Japan and many European countries. Inevitably, other countries will find that their working age populations are growing more slowly (or shrinking more rapidly) than their total populations. As this occurs, the demographic dividend may become a demographic burden depressing per capita income growth relative to growth in labor productivity.

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Relatively little is known about who benefits from the demographic dividend and who is likely to suffer if population aging turns the dividend into a burden, yet this is an important issue. First, changes in age structure may have important and persistent effects on generational differences in income, depending on the response of public and familial transfer systems. Second, whether the demographic dividend will have lasting favorable effects may depend on whether it leads to increased human and physical capital formation. This may be more likely to occur if the young are disproportionately favored by the dividend. Third, the welfare implications of the dividend, and the lower fertility that underlies it, depend on who receives the benefits. If favorable demographics lead to a higher per capita income among families that have reduced their childbearing, no spillovers are associated with the bonus. If on the other hand the dividend is shared more broadly, the positive or negative spillovers associated with the fertility decline will be more important.

Who gains from the demographic dividend depends to a large extent on how changes in the age structure influence transfers from those who are in their economically productive ages to those who are not. Young dependents rely almost exclusively on transfers from their parents, and to a lesser extent public transfers, to meet their material needs. In contrast, elderly dependents have more varied sources of support. In traditional societies, they may rely on familial transfers and their own continuing work effort. In modern economies, public transfer systems and lifecycle saving are more important.¹

Figure 1, based on the 1998 data for Taiwan which is described in more detail below, illustrates the importance of the intergenerational reallocations of income across age groups that underlie the analysis presented here. The age profile of mean earnings for Taiwan is typical of many countries, with earnings concentrated in the working ages of 20-65. The per capita income varies much less across ages than earnings, because the young receive transfers and the old receive transfers and have non-labor income.²

The importance of age structure is immediately obvious from Figure 1. The two age profiles would be impossible if there were equal numbers in each age group; the profile of per capita income could not possibly be so high unless non-labor income was much higher than it is in Taiwan. However, in 1998 Taiwan had a very favorable age distribution. About 31% were under the age of 20 and 10% were over age 65, while 59% were in the working ages 20-65. Thus, a very high income profile was consistent with the prevailing earnings profile. Given the age earnings profile, the effect of population aging in Taiwan is also clear – either non-labor income must increase substantially or per capita income must decline.

What is entirely unclear is the ages that will experience the greatest declines. Nor can we rule out the possibility that the per capita income for some age groups will actually increase at the expense of further declines in other age groups.

To address this issue, we propose a model that emphasizes intergenerational transfers and deemphasizes saving responses. We draw an important distinction between the effects of changes in population age structure and familial age structure. The reason for doing so is that public transfers are influenced by the population age structure, while familial transfers are influenced by the age structure of the family. In the analysis, the separate effects of population and family age structure are obtained by distinguishing what we call family cohorts.

The model is estimated using age-specific data from annual income and expenditure surveys conducted in Taiwan between 1978 and 1998. Taiwan's experience is instructive because it

¹For a formal and comprehensive approach to transfers and saving in a lifecycle context, see Lee (1994); Lee (2000).

²The per capita household income is the mean of the per capita income of households in which persons aged *a* live. The household income is equally shared among all household members.

experienced such a rapid fertility decline, and significant and favorable changes in age structure over the twenty-one year period analyzed. Like many other countries, however, Taiwan will experience rapid population aging in the coming decades, with unfavorable implications for per capita income.

Subject to the qualifications discussed in more detail below, the analysis leads to the following conclusions. First, changes in age structure had a favorable effect. The demographic dividend raised the per capita income by about 50% between 1978 and 1998. However, not all age groups shared equally in the gains. Second, generational differences in income per capita changed in part because of changes in the intergenerational differences in earnings. If transfers were governed by effective altruism, we would not expect this to be the case. Third, generational differences in income are influenced by both the population age structure and the family age structure. The per capita incomes of children and young adults are adversely affected by an increase in the population dependency ratio and the family dependency ratio. As a result, they benefited the most from the favorable changes in age structure during the 1980s and 1990s. In contrast, the per capita income of the elderly does not appear to have been influenced by the family age structure, and was somewhat less affected by changes in the population age structure. As a result, they have benefited less from demographic changes in the past. Fourth, demographic conditions have greatly favored some birth cohorts over others. The 1978 cohort is the most favored, with an average per capita income about 20% higher than that of the 1949 birth cohort and 30% higher than that projected for the 2014 birth cohort. Fifth, population aging will adversely influence growth in per capita income in the coming decades. We predict that, on average, the per capita income growth will be lower in the future because of changes in the age structure. This does not mean that per capita income will decline. If productivity increases continue at the same pace as over the 1978-98 period, the per capita income will increase at an annual rate of about 5.6% per year during the 1999-2030 period. Five-year-olds will experience a growth of 4.5% as compared with 5.8% for sixty-five-year-olds.

2. Age-structure, transfers, and per capita income

The labor income is taken as given in the analysis, and forecasts of per capita income are conditioned on the growth in output per worker. The per capita income can diverge from the labor income because of both transfers and non-labor factor income. In this section, however, we assume a consumption-loan economy in which all non-labor income is zero.³

Thus, the divergence of per capita labor income from earnings is modeled here as the outcome of intergenerational transfers, i.e.,

$$y(a) = y^l(a) + \tau(a), \quad (1)$$

where $y(a)$ is the per capita income of persons aged a , $y^l(a)$ is the labor income of persons aged a , and $\tau(a)$ is the net transfers to persons aged a .

Changes in age structure affect both public and private transfers. Consider first public transfers. Public transfers are subject to a social budget constraint: public transfers must sum to zero. Designating the average net transfer for the population in the dependent age groups as $\tau^g(D)$ and the average net transfer for the population in the non-dependent age groups as $\tau^g(\sim D)$:

$$-\tau^g(\sim D)N^{\sim D} = \tau^g(D)N^D, \quad (2)$$

³The empirical model estimated below does not distinguish between transfers and non-labor income. Thus, to the extent that changes in the age structure influence either, they are captured by the empirical model.

where N^D is the population in the dependent age groups and $N^{\sim D}$ is the population in the non-dependent age groups. Rearranging the terms yields the relationship between transfers and the population dependency ratio implied by the social budget constraint:

$$\frac{-\tau^g(\sim D)}{\tau^g(D)} = \frac{N^D}{N^{\sim D}}. \quad (3)$$

An increase in the dependent population must lead to a rise in the average net public transfer paid by the non-dependent population, and a corresponding decline in $y(\sim D)$; or a decline in the average net public transfer received by the dependent population and a corresponding decline in $y(D)$; or both. The social budget constraint does not rule out the possibility that an increase in the dependency ratio will lead to an expansion of transfer programs, i.e., an increase in the average transfer payment to members of the dependent population (Razin, Sadka, & Swagel, 2002). If this happens, then the tax burden on members of the non-dependent population will be even greater by virtue of the upward shift in the dependency ratio.

Several previous studies have addressed the relationship between age structure and public transfers. Preston (1984) argues that an increase in the size and political power of the elderly population has led to a rise in transfers to the elderly, accounting for a substantial improvement in their relative economic status. In contrast, Becker and Murphy (1988) argue that the rise in public pensions in the US is part of an intergenerational contract. The elderly are receiving larger public pensions as a repayment for the greater investment they made in public education programs. Recent work by Bommier, Lee, Miller, and Zuber (2004) has called the Becker and Murphy interpretation of the US experience into question, but if Becker and Murphy are correct then an increase in old age dependency has not led to greater transfers to the elderly. Gruber and Wise (2001) provide recent empirical work that is relevant to the issue. Their analysis of OECD data concludes that population aging has led to a decline in average transfers to the elderly and a rise in average tax payments by the non-elderly. The costs of higher dependency are being shared by workers and retirees.

To summarize, an increase in the population dependency ratio must lead to a decline in the per capita income of one or more age groups. If public transfers are governed by generational politics, an increase in the dependency may lead to an increase in the per capita income of the population age group with larger numbers. If public transfers are influenced by altruism, then it is more likely that all age groups will experience a decline in per capita income.

Even if changes in the population age structure lead to important changes in the age profile of public transfer programs, the effect of this on per capita income may be neutralized in part or entirely by familial transfers. If prime age earners act as effective altruists with regard to their family members, redistributions from changes in public transfers will have no effect on the distribution of consumption. Public transfers induce an offsetting change in familial transfers. Thus, an increase in the population dependency ratio may lead to a decline in the per capita income of all age groups, even if public transfer programs change in a way that is favorable to one group over another.

The effect of age structure on familial transfers is by no means limited to responses to shifts in public transfers. Families and family transfers are subject to their own budget constraints. Net familial transfers, defined as transfers within the family, must also sum to zero. Thus, an increase in the dependency ratio within the family must lead to either a decline in the average familial transfer received by dependents or an increase in the average familial transfer made by non-dependent family members. Likewise, the income of either dependent family members or non-dependent family members must decline with a rise in the family dependency ratio.

To say more about the response of familial transfers to changes in age structure requires a behavioral model of the family. There are various competing models of family transfers and extensive empirical evidence based on micro-level surveys. The theoretical models that have guided research on the determinants of transfers reflect the diverse roles of the family. Altruism and efficiency concerns are both at work in economic models of family transfers (Becker & Tomes, 1976; Becker & Murphy, 1988). Effective altruists allocate resources across the family – investing in human capital, smoothing over the lifecycle and uncertain states of the world – meeting both efficiency and distributional objectives. Lillard and Willis (1997) provide a succinct summary of the competing models. The old age security hypothesis posits that children are the old age security plan for parents. In countries with under-developed capital markets, accumulating financial wealth is not a viable option. As capital markets improve, parents can rely more on saving and less on children (Willis, 1980). The parental repayment hypothesis emphasizes constraints on borrowing to invest in human capital rather than deficiencies in capital markets. Efficient investment in human capital is achieved only if children can “borrow” from their parents. Depending on the extent of the altruism, an implicit contract may exist that requires children to repay their parents (Becker & Tomes, 1976). If the family insures members against risk, inter vivos transfers will arise when members face bouts of unemployment. Protection against longevity risk will lead to bequests by the elderly who die at a young age and support from children for the elderly who live longer than expected (Kotlikoff & Spivak, 1981).

An alternative, or perhaps complementary, approach to family transfers emphasizes the exchange motive. Transfers of money between parents and children may be implicit payments for services provided. Children may provide personal care to elderly parents with failing health. Grandparents may provide childcare services and receive “compensation” from their children (Cox, 1987). As is clear from Samuelson's (1958) seminal work, however, exchange cannot satisfy the lifecycle problems that are under consideration here.

It is empirically difficult to distinguish between alternative models of transfers. The motivations underlying transfers vary from one setting to the next, and transfers often fill a multiplicity of purposes. In studies of inter-household transfers in Malaysia and Indonesia, no single model explains transfers. The evidence there points to exchange, insurance, and repayments for educational “loans” as important motives for transfers (Lillard & Willis, 1997; Frankenberg, Lillard, & Willis, 2002). Inter-generational transfer arrangements in Taiwan are consistent with a variety of interpretations, but not the use of bequests to enforce old age support (Lee, Parish, & Willis, 1994). Altonji, Hayashi, and Kotlikoff (2000) conclude that, in the US, money transfers respond to income differences, and appear to be motivated by altruism rather than by implicit exchange. Time flows from children to parents are not accompanied by money flows from parents to children. However, the very low responsiveness of transfers to inter-generational income differences is at odds with the standard altruism model (Altonji, Hayashi, & Kotlikoff, 1992; Altonji et al., 2000).

3. The model

This paper employs a model, the overlapping families (OLF) model, which allows the analysis of intergenerational familial effects using age- or cohort-specific aggregate data. The model allows us to analyze independent effects of the family dependency ratio and the population dependency ratio. The population and family dependency ratios may differ substantially at any point in time for two reasons. First, extended families are subject to age and lifecycle effects. Over the lifecycle, families have periods of high dependency when relatively few family members are in the working ages, and period of low dependency when relatively more family members are in the working ages (Chayanov, 1966). Second, the demographic transition produces important cohort effects. During periods of fertility decline (given child mortality),

the youth dependency ratio will decline for successive cohorts.⁴ Thus, the family dependency structure will vary across cohorts, while the population dependency structure will be the same for all cohorts at any point in time.

The OLF model treats families in a highly stylized manner. A family is a kin-group, who may or may not share a residence, consisting of 3 generations: workers, their children, and the workers' pro rata share of their parents, called pensioners. We assume that all individuals are born to persons of age g , the generation length. Thus, families with workers aged a , have children aged $a-g$, and pensioners aged $a+g$. A family cohort consists of all workers born in the same year, a , and their family members. Two family cohorts are shown in Figure 2: the family cohort that consists of workers aged 30-34, pensioners aged 60-64, and children aged 0-4, and the family cohort consisting of workers aged 45-49, pensioners 75-79, and children 15-19. Although the model is represented using five-year age groups, any age grouping can be used in principle.

The distinction between the population dependency ratio and the family dependency ratio is readily illustrated using the OLF model. In Figure 3 we show the population dependency ratios and the family dependency ratios for three family cohorts, based on a generation length of 30 years. The 0-30-60 cohort consists of families containing newborns, thirty-year-olds, and sixty-year-olds in each year. The 10-40-70 and 20-50-80 cohorts are similarly defined. Thus, the family dependency ratios are dependency ratios within each family cohort. There are striking differences between the population dependency ratios and the family dependency ratios. In particular, the child population dependency ratio declined rapidly and smoothly during the historical period. The family child dependency ratio for the 10-40-70 families increased between 1978 and 1986, and then declined very rapidly. The declines in the family child dependency ratios for the 0-30-60 and 20-50-80 families were much more gradual.

We normalize on the number of workers per family, so that the number of workers per family is equal to 1. For families with workers aged a , the number of children per family is equal to $n(a-g, t)$ and the number of pensioners per family is equal to $n(a+g, t)$. The variable $n(a-g, t)$ is the ratio of the population aged $a-g$ to the population aged a (the family child dependency ratio), and $n(a+g, t)$ is defined as the ratio of the population aged $a+g$ to the population aged a (the family old-age dependency ratio).

Consider a simple consumption-transfer model. In each period, consumption by the family is constrained by the labor earnings of the family's members and net public transfers. There is no saving. Thus, per capita income and consumption are equivalent. As an accounting convenience, public transfers are assumed to flow to and from the worker generation, although the size of the transfer may depend on the age composition of the family. Familial transfers, which flow to and from the worker generation and dependent generations (children and retirees), provide the means by which any distribution of consumption can be obtained. The consumption of each dependent generation is equal to that generation's labor income and its net familial transfers. The consumption of the worker generation is equal to its labor earnings plus net public transfers plus net familial transfers. Suppose that the per capita consumption of each generation is determined by an altruistic family utility function,

$$U(c(a, t), c(a - g, t), c(a + g, t); n(a - g, t), n(a + g, t)), \quad (4)$$

subject to:

⁴If there are important changes in the timing of fertility (tempo effects), the cohort fertility will decline either more slowly or more rapidly than period measures of fertility.

$$\begin{aligned}
y^l(a, t) + \tau^p(a, t) + \tau^f(a, t) &= c(a, t), \\
y^l(a - g, t) + \tau^f(a - g, t) &= c(a - g, t), \\
y^l(a + g, t) + \tau^f(a + g, t) &= c(a + g, t), \text{ and} \\
\tau^f(a, t) + n(a - g, t)\tau^f(a - g, t) + n(a + g, t)\tau^f(a + g, t) &= 0,
\end{aligned} \tag{5}$$

where $y^l(x, t)$ is the per capita labor income of persons aged x , $c(x, t)$ is the per capita consumption of persons aged x , $\tau^p(x, t)$ is the net public transfer to households with workers aged x , and $\tau^f(x, t)$ is the net familial transfer to individuals aged x .⁵

Net public transfers received by the household are exogenous to the family decision-making process, but depend on the composition of the household, the effects of age structure on the political decision-making process, and the social budget constraint,

$$\begin{aligned}
\tau^p(a, t) &= \tilde{\tau}_2^p + n(a - g, t)\tilde{\tau}_1^p + n(a + g, t)\tilde{\tau}_3^p, \\
\tilde{\tau}_2^p + DR_1(t)\tilde{\tau}_1^p + DR_2(t)\tilde{\tau}_3^p &= 0
\end{aligned} \tag{6}$$

where $\tilde{\tau}_i^p$ is the per capita net public transfer payment to generation i (children, workers, or retirees), $DR_1(t)$ is the ratio of children to workers in the population, and $DR_2(t)$ is the ratio of retirees to workers in the population.

Suppose that the bundles of goods consumed by children, workers, and pensioners do not differ in their composition, so that changes in relative prices do not influence the family's allocation problem. If this is the case, then the share of the family's budget consumed by children, workers, and pensioners (w) will be affected only by the total family income, $y^T(a, t)$, and the population age structure, $n(a+g, t)$, and $n(a-g, t)$:

$$\begin{aligned}
w(a - g, t) &= f_1(n(a - g, t), n(a + g, t), y^T(a, t)) \\
w(a, t) &= f_2(n(a - g, t), n(a + g, t), y^T(a, t)) \\
w(a + g, t) &= f_3(n(a - g, t), n(a + g, t), y^T(a, t)),
\end{aligned} \tag{7}$$

where

$$y^T(a, t) = \tau^p(a, t) + y^l(a, t) + n(a - g, t)y^l(a - g, t) + n(a + g, t)y^l(a + g, t). \tag{8}$$

In a consumption loan economy, the per capita income by age for each of the three generations is:

$$\begin{aligned}
y(a - g, t) &= y^T(a, t)w(a - g, t)/n(a - g, t) \\
y(a, t) &= y^T(a, t)w(a, t) \\
y(a + g, t) &= y^T(a, t)w(a + g, t)/n(a + g, t).
\end{aligned} \tag{9}$$

From equations (7), (8) and (9), the social budget constraint on public transfers, and relaxing the altruism assumption, the reduced form of the per capita income by age for each of the three generations is:

$$\begin{aligned}
y(a - g, t) &= g_1(n(a - g, t), n(a + g, t), y^l(a, t), y^l(a - g, t), y^l(a + g, t), DR_1(t), DR_2(t)) \\
y(a, t) &= g_2(n(a - g, t), n(a + g, t), y^l(a, t), y^l(a - g, t), y^l(a + g, t), DR_1(t), DR_2(t)) \\
y(a + g, t) &= g_3(n(a - g, t), n(a + g, t), y^l(a, t), y^l(a - g, t), y^l(a + g, t), DR_1(t), DR_2(t)).
\end{aligned} \tag{10}$$

⁵Positive transfers are receipts and negative transfers are payments.

The earnings of dependent generations relative to the earnings of the worker generation are

measured using r_1 and r_2 , where $r_1 \equiv \frac{y^l(a-g, t)}{y^l(a, t)}$ and $r_2 \equiv \frac{y^l(a+g, t)}{y^l(a, t)}$.

A convenient empirical formulation is:

$$\begin{aligned} \ln y(a-g, t) &= \alpha_0 + \alpha_1 \ln y^l(a, t) + \alpha_2 r_1 + \alpha_3 r_2 + \alpha_4 n(a-g, t) + \alpha_5 n(a+g, t) + \alpha_6 DR_1(t) + \alpha_7 DR_2(t) \\ \ln y(a, t) &= \beta_0 + \beta_1 \ln y^l(a, t) + \beta_2 r_1 + \beta_3 r_2 + \beta_4 n(a-g, t) + \beta_5 n(a+g, t) + \beta_6 DR_1(t) + \beta_7 DR_2(t) \\ \ln y(a+g, t) &= \gamma_0 + \gamma_1 \ln y^l(a, t) + \gamma_2 r_1 + \gamma_3 r_2 + \gamma_4 n(a-g, t) + \gamma_5 n(a+g, t) + \gamma_6 DR_1(t) + \gamma_7 DR_2(t). \end{aligned} \quad (11)$$

Thus, the per capita income of any generation depends on the earnings of workers, the earnings of children and pensioners relative to workers, and the child and old-age family and population dependency ratios.

We can elaborate several hypotheses from equation (11). Some of the following hypotheses are linked to each other. Thus, if one hypothesis is rejected, then it affects the other hypotheses. However, we can still compare the size of the effects across generations because the measures of the independent variables are identical across all three regressions.

First, in a true consumption-loan economy α_1 , β_1 , and γ_1 may not all be greater than 1 given r_1 and r_2 . One generation can gain only relative to its earnings at the expense of another generation's loss. If preferences are homothetic and effective altruism governs transfers, then these coefficients would not be significantly different from 1, and the age structure will be independent of the generational distribution of income. The existence of non-labor income adds additional complications. If a growth in earnings is associated with a change in the relative importance of non-labor income, then the per capita income for any age group may grow either more rapidly or more slowly than labor income.

Second, if the family is altruistic, then the income of each generation will be independent of their share of the family earnings contributed by members of that generation. That is, given effective altruism, we expect $\alpha_2 = \alpha_3$; $\beta_2 = \beta_3$; $\gamma_2 = \gamma_3$. Homothetic preferences and effective altruism together imply that the coefficients are all zero. If the results are inconsistent with the pure altruism hypothesis, then the magnitude of these coefficients will depend on the degree of altruism governing transfers.

Third, if preferences are homothetic and the family is altruistic, then changes in family age structure are neutral with respect to the generational distribution of income. In this case, we would expect $\alpha_4 = \beta_4 = \gamma_4$ and $\alpha_5 = \beta_5 = \gamma_5$, and that all will be negative. If either altruism or homothetic preferences fails, then the income effect of dependency will differ across generations, although at least one coefficient must be negative due to the familial budget constraint.

Fourth, there is only an income effect associated with changes in public transfers induced by an increase in the population dependency ratio. Given the social budget constraint, an increase in either the youth dependency ratio or the old age dependency ratio must produce a decline in per capita income given per capita earnings. Thus, the coefficients of the population dependency ratio will be negative. If altruism holds and tastes are homothetic, all generations will experience an equivalent percentage decline in their incomes with an increase in the population dependency ratio, i.e., $\alpha_6 = \beta_6 = \gamma_6$ and $\alpha_7 = \beta_7 = \gamma_7$.

4. Empirical analysis

Although the major emphasis of this paper is methodological, the analysis of income growth in Taiwan is of interest in its own right. Taiwan has experienced rapid demographic and economic change. The life expectancy at birth increased from roughly 25 in 1900 to 78 for females and 72 for males in 1999. The total fertility rate declined from over 6 births per woman in the 1950s to replacement level by 1984. The age structure has changed rapidly. Since 1960, Taiwan's economy has been among the most dynamic in the world. How demographic change has affected economic growth and transfer systems in Taiwan could be an important development policy issue.

4.1 Data for empirical analysis

The values of all variables that comprise the synthetic panel are constructed from the Survey of Family Income and Expenditure in Taiwan (FIES), also known as the Survey of Personal Income Distribution in Taiwan until 1993. The number of households surveyed has varied over time, but the sample size is more than sufficient for our purpose. In 1998, about 0.4 percent of all households (14,031 households and 52,610 individuals) were interviewed. These are not panel data, but repeated cross-sections.

The data set consists of mean values for single-year family cohorts for 21 consecutive years. The generation length g is set to 30 years. This estimate is based on the differences in the average ages of the different generations observed in the sample. The generation length is quite stable across time for family cohorts under the age of 50.⁶ Thus, the data consists of 30 family cohorts for each year, consisting of workers aged 30-59, their children aged 0-29, and seniors aged 60-89. Those aged 90 and older are included with the 89-year-old pensioners. Thus, the data set consists of 21 years times 30 age groups, yielding 630 observations. The oldest members were born in 1891 and the youngest in 1998, but for these two groups we have only one observation. Family cohorts with workers born near the middle of the span of birth years covered (1955) can be tracked over the entire 21-year span of the data.

An attractive feature of the FIES is that each component of the household income is assigned to members of the household. Although there is a residual category for income that cannot be assigned to an individual, this category is rarely used. Consequently, we can calculate earnings, defined as wages plus two thirds of the business income, separately for each generation by age. The per capita household income is estimated for each household member by dividing the total current disposable income equally among all household members. The average earnings and per capita income by age are estimated using sample weights.

The family dependency ratios in Figure 3 are obviously a noisy measure of the true family dependency ratio, in part because the generation gap is not exactly 30 years and it differs between households. To diminish the potential bias from this problem, we use a five-age moving average to measure family dependency ratios. Thus, the number of observations is decreased to 546.

The source of information for population forecasting is the Projection of the Population of Taiwan conducted by the Taiwan Council for Economic Planning and Development. The data includes the Taiwan population projection between 1951 and 2101. The data set is used for both the counterfactual analysis and forecasting income.⁷

⁶For older cohorts the age difference declines, due to the effects of mortality on the survival of pensioners leading to an underestimate of the generation length.

⁷Although we focus on our income forecast for the period 1978-2030, we do need the projection data of 1951-1977 and 2031-2101 to construct the lifetime income by birth cohorts.

4.2 Regression results

Regression estimates for the per capita income of each generation are reported in Table 1. All regressions are estimated using ordinary least squares. We include the combined population dependency ratio instead of distinguishing between the child dependency ratio and the old age dependency ratio, due to the extremely high correlation between these two variables ($\rho=0.990$). The augmented Dicky-Fuller test statistic suggests that there is no unit root in the model. All estimates in this paper were obtained using the consistent variance-covariance matrix estimator of White (1980). The standard errors are thus robust to heteroscedasticity.

The coefficient of the log earnings of workers (*l_{earn}*) captures the effect of general increases in earnings because the ratios of worker earnings to children and pensioner earnings are controlled. The coefficients of the log earnings of workers are positive and significant at the 1 percent level for all regressions. The larger coefficient for the worker generation (*g₂*) implies that earnings growth leads to an increased concentration of per capita income in the worker generation. The *l_{earn}* coefficient for the worker generation, however, is not significantly different from that for the pensioner generation. The fact that the coefficients are significantly less than one suggests that the share of non-labor income has increased over time.

The coefficients of the earnings ratios between generations (r_1 and r_2) are positive for all regressions, and they are also statistically significant. If the earnings of the child generation increase, while the earnings of other generations are held constant, the per capita income of all generations increases. Likewise, if the earnings of the pensioner generation increase, all generations enjoy an increase in their per capita incomes. This supports a weak form of altruism. However, the distribution of per capita income is by no means entirely independent of the distribution of earnings. Any change always favors the generation experiencing a relative increase in its own income. Thus, we reject the pure effective altruism hypothesis.

An interesting feature of the results is that transfers do not favor adjacent generations. The pensioner generation gains as much as the worker generation from an increase in the earnings of the child generation. Likewise, the gain for the child generation resulting from an increase in the earnings of the pensioner generation is not significantly different from the gain for the worker generation.

The estimated effects of age structure are consistent with social and familial budget constraints. An increase in any dependency ratio must lead to a decline in the per capita income of one or more of the generations. An increase in the family child dependency ratio leads to a significant decline in the per capita income of the child generation; an increase in the family old-age dependency ratio leads to a significant decline in the per capita income of the child and worker generations; and an increase in the population dependency ratio leads to a significant decline in the per capita income of all three generations. Other effects are statistically insignificant.

The estimated effects of age structure vary substantially across generations. In particular, the pensioner generation appears to be less susceptible to changes in the age structure. Their per capita incomes are not affected by changes in the family dependency ratios. The estimated effect of the population dependency ratio is somewhat less than for the other generations, although the difference is not statistically significant. This suggests that the pensioner generation gained less from the favorable changes in age structure that have occurred in Taiwan and that they will suffer less from the unfavorable changes on the horizon. The counterfactual analysis presented below confirms that this is the case.

In contrast, the per capita incomes of the child and worker generations are more sensitive to changes in the age structure. Children were the only generation to benefit from a decline in the

familial child dependency ratio, although the effects of the population dependency ratio are much stronger.

A surprising feature of these results is the strength of the population dependency ratio relative to the familial dependency ratio. As discussed above, the familial dependency ratio should have a stronger effect on per capita income when transfers are primarily familial, whereas the population dependency ratio may have a stronger effect when transfers are primarily public. Given the importance of family transfers to children, our expectation was that the family age structure would have a much more important effect on the per capita income of the child generation than the population age structure. The child generation is the only generation for which the family child dependency ratio is negative, however the population dependency ratio has a much stronger effect. It is unclear exactly what mechanism would lead to this result.

Even in the case of the pensioner generation, the strength of the population dependency ratio and the weakness of the familial dependency ratios are surprising. A high percentage of the elderly in Taiwan still co-reside with their children. Public transfers have increased in recent years, but are a much smaller share of the incomes of the pensioner generation than would be the case in the US, Europe, or many Latin American countries.

It may be that a more refined measure of the familial dependency ratios than the ones used here would lead to larger estimated effects. This is an issue that warrants further attention in future research.

4.3 Counter-factual analysis

The historical implications of changes in earnings and aging for transfers are assessed using simulation techniques. We construct a series of counter-factual simulations that allow dependency structures to change in accordance with their observed historical trends, while holding all other variables constant at their 1998 levels. Using the coefficient estimates reported in Table 1 we calculate how per capita income would have evolved given the counter-factual values. All calculations employ the observed values by single years of age for the year in which the calculations are being made. Results for selected ages are presented in Table 2.

The combined effects of changes in age structure on per capita income between 1978 and 1998 were very substantial in Taiwan. The increase in per capita income due to changes in age-structure (A+B+C) ranged from 38.5% for 35-year-olds to 50.1% for five-year-olds. The effect was a substantial share of the total increase in per capita income in Taiwan during the entire period (column E). Demographic change accounted for between 13.8 and 20.9 percent of all economic growth. The effects are somewhat smaller than other estimates of the demographic bonus (Bloom & Williamson, 1998; Mason, 2001a), however the estimates are robust to slight changes in the specification and the definition of income.

The dominance of the population dependency ratio as compared to the familial dependency ratio is clear from the counterfactual analysis. The familial child dependency ratio had a negligible effect for all ages reported in Table 2 except five-year-olds. The rise in the familial old-age dependency ratio has a modest negative effect for the non-elderly, reducing the per capita income by about 10% over a twenty year period. The negative impact of the old-age family dependency ratio was overwhelmed by the favorable effect of the population dependency ratio.

4.4 Forecasting Income by Age

We use the empirical results to forecast income until 2030. Obviously our forecast belongs to the regression based econometric models rather than time-series based models. The usual problem of the regression based econometric models is that we need to know the future values

of independent variables. In this paper, we focus on *conditional forecasts*, in which the value of the future population structure is given. Thus, although the forecast involves unconditional forecasting elements, we are mostly interested in the effect of the population structure on per capita income, contingent on knowing the future population structure.

Based on the projected dependency structure, we simulate the net effects of changes in the dependency structure on per capita income, allowing dependency structures to change while holding the other variables constant at 1998 level. Regression estimates are again used to forecast what the per capita income would be by birth cohort if only the population structure changed.

Table 3 documents the total effect of all dependency ratios up to year 2030 by age and by birth cohort. One follows a birth cohort over time by moving horizontally across columns within the same row. One follows the same age group over time by moving downward along a diagonal. Within a cohort, income changes over time are attributable to age effects. In contrast, changes in income within an age group are due to cohort effects. Because all other variables are held constant at their 1998 levels, there is no time effect resulting from productivity changes.

The table suggests that the demographic dividend varies substantially by age. For example, the log income of age 0 (the bottom diagonal) decreases from 12.39 in 2011-2020 to 12.07 in 2021-2030, when population aging turns the dividend into a burden. However, the decrease for age 90 (the top diagonal) is much less, from 12.66 to 12.52. Likewise, the effect of a change in the dependency ratios is not neutral across birth cohorts. The log income of the 1991-2000 birth cohort increases from 12.31 to 12.61 as they move from age 0 to age 10. However, the log income of the 2001-2010 birth cohort changes little (12.62 to 12.63) for the same change in age.

Figure 4 summarizes the effect of all dependency ratios by age over time. The figure indicates that child generations will suffer most when population aging turns the dividend into a burden, and that pensioners will suffer the least from population aging.

Which birth cohort benefits the most from changes in age structure? To answer the question, we use predicted values of income at each age for cohorts born between 1949 and 2014, holding all other variables constant.⁸ To construct population and family dependency ratios, we use a population projection for 1951 to 2101 provided by the Taiwan Council for Economic Planning and Development. Figure 5 presents the results: the log of income averaged over the available ages for each birth cohort. Figure 5 indicates that it is people born between 1974 and 1983 who benefit the most from demographic change. The 1978 cohort is most favored, with an average per capita income about 20% higher than that of the 1949 birth cohort and 30% higher than the 2014 birth cohort. The adverse effects of demographics among future generations are felt by cohorts born after 2004. Relative to the 1949 birth cohort, the demographic dividend is entirely dissipated by 2008.

Although the mortality decline made an important contribution to the changes in age structure that underlie the demographic dividend, the precipitating event was the fertility decline. Of particular policy interest, then, is whether the gains in per capita income accrued to those who decided to have fewer children, or to someone else? A comparison between the gains charted in Figure 5 and Taiwan's total fertility rate (TFR) sheds light on this issue.

⁸Predicted values are available only for ages 2-27, 32-57, and 62-87 because of our reliance on five-year moving averages of family dependency ratios. Thus, the counter-factual values are simple averages for these age groups. The earliest birth cohort for which predicted values can be obtained for all included ages is the 1949 birth cohort, which was age 2 in 1951. The latest birth cohort for which calculations are possible is the 2014 birth cohort, which would have been 87 in 2101.

Roughly speaking, the greatest beneficiaries were members of the first low-fertility birth cohorts – the children of those who chose to have lower fertility. Their advantage relative to their parents is that they experienced low child dependency, both in their families and in their population, throughout their entire lives. Their parents, on the other hand, experienced high child dependency during their childhood and low child dependency only as workers and pensioners. Because both generations had few children, they will both experience elevated old-age dependency ratios when they become pensioners. The continued dissipation of the dividend in Figure 5 reflects continued improvements in life expectancy and the consequent rise in the proportion of the population at older ages.

Based on the regression results, we also forecast the log per capita income by age, allowing productivity to increase. We predict log earnings using the year, age and age squared. The relative income variables, r_1 and r_2 , exhibit irregular trends that are implausible for some ages. Consequently, we assume that the ratios of earnings by generation (r_1 and r_2) are fixed at the average of the 1978-1998 level. The forecasts are also conditioned on the projected population age structure. Figure 6 presents the results. If productivity increases continue at a pace consistent with those of the 1978-98 period, the per capita income will increase at an annual rate of about 5.6% per year during the 1999-2030 period. Five-year-olds will experience a growth of 4.5%, as compared with 4.9% for thirty five-year-olds and 5.8% for sixty-five-year-olds. Twenty-year-olds will experience a growth of 5.6%, as compared with 5.8% for fifty-year-olds and 6.0% for eighty-year-olds.

5. Conclusion

Previous studies of the effects of age structure on income do not consider the possibility that effects differ by age group. If public transfer programs are influenced by the age structure – and the available evidence suggests that this is the case – then it seems likely that the gains and losses associated with the demographic transition may be shifted across age groups, protecting some and burdening others. The public sector is not, however, the only force at work. In many countries, families play an important role in allocating income across generations or age groups. One possibility is that they will neutralize the intergenerational transfers undertaken by the public sector, as suggested by Barro (1974). However, in many societies, the public sector plays a relatively modest role – particularly with regard to children, but also with respect to the elderly.

Family transfers may be influenced by the family's age structure in ways that are very similar to the ways that public transfers are influenced by the population age structure. For either unit, changes in age structure can lead to either tighter or more relaxed budget constraints. However, at any point in time the demographic situation for families will differ from that of the population. This is true because families have a demographic lifecycle, with favorable demographics at some ages and less favorable demographics at others. It is also true because families which are alive at the same time have different demographic experiences. Especially in a country with rapid demographic change, the completed family size can vary considerably from one cohort to the next.

An integrated analysis of population and family-level age effects is not common in the literature because it seems to involve different levels of analysis. The overlapping families (OLF) model proposed here offers one approach to dealing with the problem. The model relies on a highly stylized view of the family. One way to improve on the research presented here would be to refine the way in which the family is modeled within the OLF framework.

The empirical results in this paper lead to several interesting conclusions. First, both the population age structure and the family age structure influence the per capita income. The

population age structure, however, has a much stronger effect than family age structure. This result seems surprising to us, especially for a society like Taiwan's, and warrants further attention. Second, the analysis provides support for only a weak form of altruism. Increased earnings among the members of one generation lead to higher incomes for members of other generations. A surprise here is that adjacent generations do not benefit more than non-adjacent generations. If the earnings of pensioners decline, for example, the incomes of workers and children are adversely affected by roughly equal amounts.

Who gained from the demographic dividend? The biggest winners were members of the first low-fertility generation – not the parents who first chose to have low fertility. The parents did gain, but by less than their children. The policy implications of this depend to some extent on one's view of the world. If the gains were to the children of those who decided to have lower fertility and parents are altruistic towards their children, then gains to children were captured by their parents. The empirical work presented here casts doubt on this view in two ways. First, the empirical analysis supports only a weak form of altruism. Second, the population dependency ratios have much greater force than the family dependency ratios. This suggests social reallocations of the gains from the fertility decline that limit the extent to which they are captured by those who opt to have fewer children.

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Figure 1.
Average earnings and per capita household income by age (1998, Taiwan \$)

Figure 2.
The Overlapping Families Model

Figure 3-A. Projected population dependency ratios

**Figure 3-B. Projected family dependency ratios
(Age 0-30-60)**

**Figure 3-C. Projected family dependency ratios
(Age 10-40-70)**

Figure 3.
Projected population and family dependency ratios

Figure 4.
Counterfactual analysis: the demographic dividend by age (1978-2030)

Figure 5.
Counterfactual analysis: mean of the log income by birth cohort (1949-2012)

Figure 6: Forecast of ln income by age: Age 5 **Age 20**

Figure 6.
Forecasts of log income by age (1978-2030)

Table 1
Regression results, ln of per capita income, Taiwan, 1978-98

	Children (g1)	Workers (g2)	Pensioners (g3)
lnearn(a,t)	0.691 (0.025)	0.775 (0.025)	0.731 (0.043)
r1(g1/g2)	0.442 (0.016)	0.291 (0.016)	0.293 (0.028)
r2(g3/g2)	0.083 (0.038)	0.137 (0.047)	0.594 (0.068)
n(a-g,t)	-0.096 (0.013)	-0.006 (0.013)	0.015 (0.019)
n(a+g,t)	-0.573 (0.072)	-0.712 (0.077)	-0.132 (0.104)
N(t) population	-0.917 (0.047)	-0.928 (0.049)	-0.830 (0.090)
R2	0.987	0.988	0.976
Number of obs.	546	546	546

Table 2
Counterfactual analysis of effects of age structure on per capita income, earnings held constant at 1998 values

	A D(kid)	B D(old)	A+B Total family dependency	C Population dependency	D A+B+C	% increase in Y (E)	Demographic dividend (D/E)
Age 5	9.8%	-11.4%	-1.6%	51.7%	50.1%	277%	18.1%
Age 20	3.0%	-8.4%	-5.4%	51.7%	46.4%	222%	20.9%
Age 35	0.7%	-14.4%	-13.7%	52.2%	38.5%	279%	13.8%
Age 50	0.2%	-10.5%	-10.3%	52.2%	41.9%	263%	15.9%
Age 65	-1.6%	-2.5%	-4.1%	48.3%	44.1%	254%	17.4%

Table 3
Counterfactual analysis of the effects of age and year of birth on ln of per capita income

Birth cohort	Year			
	1981-1990	1991-2000	2001-2010	2011-2020
1891-1900	11.96			
1901-1910	12.05	12.34		
1911-1920	12.03	12.37	12.53	
1921-1930	12.15	12.35	12.57	
1931-1940	12.26	12.48	12.55	12.66
1941-1950	12.14	12.57	12.67	12.62
1951-1960	12.10	12.48	12.80	12.60
1961-1970	12.04	12.44	12.72	12.70
1971-1980	11.94	12.38	12.64	12.85
1981-1990	12.08	12.36	12.66	12.72
1991-2000		12.38	12.61	12.59
2001-2010			12.62	12.73
2011-2020				12.63
2021-2030				12.39
				12.07