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Labor Force Aging and Growth of Per-Worker Income

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Abstract

We provide a theoretical mechanism behind which the labor force aging adversely influences economic growth by developing a human-capital based growth model in which human capitals embodied in people of different age cohorts are imperfect substitutes as inputs in production. The age distribution in the labor market can significantly influence wage profiles, the young's incentive of investing in human capital, and eventually economic growth. We observe the cross-country empirical evidence showing that the advance of the labor force aging leads to a slowdown of the subsequent economic growth of per worker GDP.

Keywords: Economic Growth, Human Capital, Labor Force Aging

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1. Introduction

As the episode of the ruin of the Roman Empire tells, a matured society with aging population is declining. In a matured society, a smaller proportion of young people face less pressure of competition, and have less incentive to invest in acquiring knowledge or human capital, but rather exploit benefits of the existing knowledge. The proceeding quote from the French demographer, Alfred Sauvy, reveals that "such a society (with aging population) would hold a society of old people, living in old houses, ruminating about old ideas". Sauvy attributed the slow technological progress in nineteenth century France to conservatism and aging. Furthermore, he says, “Under the influence of population aging, the French government and Parliament subsidized the Navy’s sailing ships while other countries were adopting steam-powered craft.

Economic theories, however, have not yet provided any clear-cut answer to the impacts of demographic change on economic activities, but rather demographic factors are suppose to influence the economy through various channels. One strand of literature argues a negative impact of population growth on the economy. The standard growth theory argues the negative role of population growth on the level of per-capita income since the seminal work of Solow (1956). Becker and Barro (1988) emphasize the negative role of fertility on economic growth. On the other hand, another strand of literature argues the positive role of population growth on the economy. Kuznets (1960) and Simon (1977, 1981) argue that a higher population means more inventors. Kremer (1993) and Jones (1998) argue that an increased population raises returns to new ideas and promote economic growth. Glaeser *et al* (1992), Ciccone and Hall (1996), and Srinivasan and Robinson(1997) argue that more populated cities or an increase in the size of employment can speed up the accumulation of human capital and knowledge.

Empirical evidence also provides conflicting evidence. Barro (1991), Mankiw, Romer, and Weil (1992), and Brander and Dorwick (1994) find that fertility or the population growth will be negatively linked to per-capita income growth. On the other hand, Galor and Zang (1997) and Williamson (1997) find that the growth rate of the labor force has a positive effect on per-capita income growth. Kremer (1993) finds empirical evidence supporting the view that total research output and hence per-capita income will increase with population.

There may be another channel that should not be overlooked through which a demographic element influences economic growth. In practice, Germany, Italy, and Japan attained rapid and sustained growth with low unemployment rates after World War II. The successes of these countries are supposed to be relevant to the large replacement of elder by younger in the workplace. In addition, growth miracle in the East Asian countries has been accompanied by an increasing working-age population, which Bloom and Williamson (1997) call "demographic gift".

This mechanism is going to reverse itself in the 21st century. Advanced countries have experienced a fall in fertility and a rise in life expectancies over the last two decades, and are going to face the decreased working population and the labor force aging. Figure 1 shows the share of workers aged 20-39 to all workers in all OECD countries. A number of countries including Japan, Denmark, Finland, Iceland, and Sweden have experienced the decline in the share of workers aged 20 to 39. Other countries except Ireland are supposed to face the similar tendency by 2000 or 2010. This figure reveals that the aging in the labor force is a serious problem in many advanced countries.

The main idea that we advocate in this paper is that the labor force aging of the consequent increased elder relative to young workers provide a disincentive for young people to invest in human capital, and eventually deters economic growth. We present a human-capital based growth model in which human capitals embodied in people of different age cohorts are imperfect substitutes as inputs in production. This notion goes back to Welch (1979) who found the greater wage difference between new entrants and peak earners when the baby boom cohorts entered the labor market in the United States. Murphy and Welch (1992) found that workers with similar ages and education level tend to be substitutes, but those with different ages and education levels are complements in the United States. Also in Japan, Inoki and Ohtake (1997) found that the baby boom cohorts earn the smaller lifetime earning relative to other cohorts.

An increase in the size of a generation or a cohort increases competition among people of this generation or cohort, driving down their wage rate relative to the one of the elder, and forcing them to make more effort to acquire skills for getting future higher salaries. In the aged society with abundant elder and scarce young, young people take the "myopic" behavior in investment in human capital due to this adverse incentive effect.

We investigate the empirical analysis to find this hypothesis using the pooled data for OECD countries. The estimation result shows that an advance of the labor force aging leads to a decline in the subsequent economic growth rate of per worker GDP. Forecasting per worker GDP growth for 2000-2010 and 2010-2020, we observe that the growth rate for 2010-2020 will be smaller than the one for 2000-2010 in all countries except for Ireland.

2. The Model

We present an overlapping-generations economy in which agents live for two periods and people of different generations are linked through altruism. The economy consists of agents who live for two periods and sufficiently large numbers of firms that produce a single good competitively. The production process requires physical capital and two types of workers, skilled and unskilled workers. Two types of workers perform different tasks: skilled workers engage in management and unskilled workers work as laborers. As argued just below, young agents are identified with unskilled workers, and old agents identified with skilled workers or managers.

Each of agents is born with endowment of one unit of the productive time in both the first and the second period of life. Each of them consumes only in the second period of life. In the first period of life, each of them receives bequest from his parent and decides how much time to allocate between supplying in the labor market and investing in human capital. In the second period of life, each of them supplies one unit of time in the labor market. Each of them consumes only in the second period of life. At the beginning of the second period of life, each parent gives birth to $1+n_{t+1}$ children. We call the generation that appears at period t, "generation t". Letting N_t denote the size of generation t and $1+n_{t+1} = N_{t+1}/N_t$ denote the population growth rate, the total number of labor employed at period t, denoted L_t, is equal to $N_t + N_{t-1}$. The share of young workers to the total labor is $(1+n_t)/(2+n_t)$, the share of elder workers is $1/(2+n_t)$, and hence the evolution of the total labor is

$$\frac{L_{t+1}}{L_t} = \frac{(2+n_{t+1})(1+n_t)}{2+n_t}.$$

The utility of an individual of generation t, V_t, depends positively not only on his own second-period consumption c_{t+1} but also on the welfare of each of his children given by V_{t+1}:

(2-1) $$V_t = \frac{1}{1+\rho}\{\log c_{t+1} + (1+n_{t+1})V_{t+1}\},$$

where ρ is a subjective discount rate, and n_{t+1} is assumed to be less than ρ. Although we basically investigate the economy with a constant population growth rate, for later analytical convenience we denote time subscript for n.

An agent born at t is endowed with an amount of human capital h_t^e. By investing u_t units of time in human capital, he can accumulate the amount of human capital up to h_t^y in the remaining first period of life and up to h_{t+1}^o in the second period of life according to the Micerian human capital investment functions, with

(2-2) $h_t^y = \theta H(u_t)h_t$, and $h_{t+1}^o = H(u_t)h_t$,

where $u_t \in [0,1]$ is the fraction of productive time devoted to the accumulation of human capital and $H(.)$ is increasing, concave and continuously twice differentiable function; $H(.)$ satisfies $\lim_{u_t \to 0} H'(u_t) = +\infty$, $\lim_{u_t \to 1} H'(u_t) = 0$, and $H(0) = 1$, and $0 < \theta \le 1$. Equation (2-2) implies the feature of decreasing returns to human capital that captures the common recognition that people accumulate human capital rapidly when they are young, but less rapidly when they get elder.[1] Psacharopoulos (1994) surveys evidence from many countries on returns to investment in education, finding that the rate of return is highest in primary education, next in secondary education, and lowest in higher education. The assumption of $0 < \theta \le 1$ may capture the fact that, as the actual earning profiles reflect, even highly educated young workers accumulate more human capital through the post-schooling investment including the acquisition of skills and experiences in the workplace. Without of loss of generality we assume that $\theta = 1$.

In order to motivate the intergenerational transfer of human capital, assume that younger agents inherit a fraction of the average level human capital of agents of the preceding generation, that is,

(2-3) $$h_{t+1}^y = (1-\delta)\bar{h}_{t+1}^o ,$$

where $\bar{h}_{t+1}^o$ is the average stock of human capital of older agents at period t+1. Note that the

[1] Empirical estimates of human capital production function indicate that the returns to private inputs are diminishing (e.g., Heckman (1976) and Haley (1976)).

initial level of human capital is given by h_0^o. Children are brought up with better educational environment in countries with higher average education level of adults. The parameter δ captures the extent of inheritance of human capital which we set to be zero in order to simplify the analysis. Investment in human capital may involve the formal education and the post-schooling education that is made in the workplace to acquire skills and experiences needed to perform jobs.

A single good can be produced, consumed, accumulated as physical capital. We assume that all firms are identical and the production in period t requires three inputs: physical capital saved by individuals of generation t-1, human capital of young workers of generation t, and human capital of elder workers of generation t-1. Under the constant-returns-to-scale technology, the production function at the aggregate level is represented as the following technology:

(2-4) $$Y_t = AK_t^{\alpha}\left[\left(1-u_t\right)N_t h_t^y\right]^{\beta}\left[N_{t-1}h_t^o\right]^{1-\alpha-\beta} \ ; \ 0<\alpha<1, 0<\beta<1, A>0 \ ,$$

where Y_t is the output of the single good, K_t is the aggregate physical capital stock, $\left(1-u_t\right)N_t h_t^y$ and $N_{t-1}h_t^o$ are the aggregate efficient unit of time supplied by young and elder workers, respectively, and A is an exogenous technological parameter. Physical capital fully depreciates after one period. Competitive firms choose three different kinds of capital so as to maximize the current profit, taking factor prices as given.

A crucial feature of (2-4) is that human capital of young and elder workers are 'imperfect substitutes'. Young workers have a comparative advantage in specializing tasks that they learned in the school, while elder workers who acquired skills and experiences in the workplace have a comparative advantage in managing the organization. Empirical evidence supports the notion that human capital of young and of elder workers are imperfect substitutes. Welch (1979) estimates that a 10 % increase in cohort size reduced wages of college graduates by 9 % and of high-school students by 4 % on entry into the labor market. Freeman (1979) finds that such a model could explain the differential change in the relative wages of younger and elder workers over the period in which the Baby Boom cohort entered the labor market. Murphy and Welch (1992) find that workers with similar ages and education level tend to be substitutes, but those with different ages and education levels are complements. Korenman and Newmark (2000), using time-series data on OECD countries, find that an increase in the youth share of the working age population raises the youth unemployment rate relative to the prime age unemployment.

3. The Equilibrium in the Balanced Growth Path

In this section we characterize an equilibrium of this economy. Under the assumption that individuals are identical within generations, we will obtain $\overline{h}_t^o = h_t^o$ in equilibrium. From this and (2-3), we obtain $h_t^e = h_t^o$. Letting $k_t \equiv K_t / L_t$ denote the physical capital divided by the total number of workers, the firm's profit maximization yields following optimality conditions,

(3-1) $$1 + r_t = \alpha A \left(\frac{k_t}{h_t^0} \right)^{\alpha - 1} (1 - u_t)^{\beta} H(u_t)^{\beta} (1 + n_t)^{\beta} (2 + n_t)^{\alpha - 1},$$

(3-2) $$w_t^y = \beta A \left(\frac{k_t}{h_t^0} \right)^{\alpha} (1 - u_t)^{\beta - 1} H(u_t)^{\beta - 1} (1 + n_t)^{\beta - 1} (2 + n_t)^{\alpha},$$

(3-3) $$w_t^0 = (1 - \alpha - \beta) A \left(\frac{k_t}{h_t^0} \right)^{\alpha} (1 - u_t)^{\beta} H(u_t)^{\beta} (1 + n_t)^{\beta} (2 + n_t)^{\alpha} \quad ,$$

where r_t is the real interest rate, and w_t^y and w_t^o are wage rates of labor supplied by young and elder workers, respectively.

We now turn to the decision problem of individuals. Each young agent of generation t receives bequest from his parent, and earns the labor income by supplying $1 - u_t$ units of time in the labor market. The budget constraint of a young individual in period t is

(3-4) $$w_t^y (1 - u_t) h_t^y + b_t = s_t,$$

where $w_t^y (1 - u_t) h_t^y$ denotes the labor income earned, b_t is the bequest that he receives from his parent, and s_t is the saved income. When this agent is matured, he earns the labor income and the interest income from his savings. These earnings are distributed between consumption and physical bequest to his offspring. Thus, the budget constraint of an old individual in period t+1 is

(3-5) $$\left(1+r_{t+1}\right)s_t + w_{t+1}^o h_{t+1}^o = c_{t+1} + \left(1+n_{t+1}\right)b_{t+1},$$

where $w_{t+1}^o h_{t+1}^o$ denotes labor income earned when he is old.

The problem of an individual is to choose c_{t+1}, u_t and b_{t+1} in order to maximize the utility (2-1), subject to (2-2), (2-8), (2-9), and taking the predetermined variables h_t^e, b_t, and factor prices as given. Keep in mind that agents solve the problem not by taking the relation $h_t^e = h_t^o$ into account. The optimality condition for consumption is given by

(3-6) $$c_{t+1} = \frac{(1+r_{t+1})c_t}{1+\rho}.$$

Finally, the agent choose the time for investment in human capital to equal the marginal cost and the marginal benefit of investing one extra unit of time, satisfying

(3-7) $$w_t^y H(u_t) = w_t^y (1-u_t) H'(u_t) + \frac{w_{t+1}^o}{1+r_{t+1}} H'(u_t).$$

The LHS is the marginal cost of spending extra time on investment in human capital, and is expressed as the forgone wage, while the RHS is the marginal benefit of that extra time. The benefit is composed of two terms, that is, the benefit from increasing human capital in the first period of life and the one in the second period of life.

The equilibrium in the good market implies

(3-8) $$K_{t+1} = Y_t - C_t.$$

A competitive equilibrium must satisfy optimality conditions of firms, (3-1), (3-2), (3-3), those of households, (3-6), (3-7), the equations of the motion for human capital (2-2), (2-3), and the good-market-clearing condition (3-8), with the consistency condition $\bar{h}_t^o = h_t^o$, at every period. An equilibrium in the decentralized economy evolves according to the following four-dimensional system with four variables $\{k_t, h_t, c_t, u_t\}$:

(3-13) $$\frac{k_{t+1}}{k_t} = A\frac{(2+n_t)^\alpha}{2+n_{t+1}}(1+n_t)^{\beta-1}\left(\frac{k_t}{h_t}\right)^{\alpha-1}(1-u_t)^\beta H(u_t)^\beta - \frac{2+n_t}{(2+n_{t+1})(1+n_t)}\frac{c_t}{k_t},$$

(3-14) $$\frac{c_{t+1}}{c_t}=\frac{\alpha A}{1+\rho}\left(\frac{k_{t+1}}{h_{t+1}}\right)^{\alpha-1}(1-u_{t+1})^{\beta}H(u_t)^{\beta}(1+n_{t+1})^{\beta}(2+n_{t+1})^{\alpha-1},$$

(3-15) $$\frac{k_{t+1}}{h_{t+1}}=\frac{\alpha\beta A\{H(u_t)-(1-u_t)H'(u_t)\}}{(1-\alpha-\beta)H'(u_t)}\left(\frac{k_t}{h_t}\right)^{\alpha}(1-u_t)^{\beta-1}H(u_t)^{\beta-1}\frac{(1+n_t)^{\beta-1}(2+n_t)^{\alpha}}{2+n_{t+1}},$$

and

(3-16) $$\frac{h_{t+1}}{h_t}=H(u_t),$$

where we use new variable $h_t\equiv h_t^e=h_t^o$. By defining new a variable $X\equiv k/h$, we can reduce the system (3-13)-(3-16) to the two-equation system with two variables, X_t and u_t:

(3-17) $$X_{t+1}=\frac{\alpha\beta A\{H(u_t)-(1-u_t)H'(u_t)\}}{(1-\alpha-\beta)H'(u_t)}X_t^{\alpha}(1-u_t)^{\beta-1}H(u_t)^{\beta-1}\frac{(1+n_t)^{\beta-1}(2+n_t)^{\alpha}}{2+n_{t+1}},$$

and

(3-18) $$1-\frac{\alpha\beta H\{(u_{t+1})-(1-u_{t+1})H'(u_{t+1})\}}{(1-\alpha-\beta)(1-u_{t+1})H'(u_{t+1})}$$
$$=\frac{\alpha(2+n_{t+1})(1+n_t)}{(1+\rho)(2+n_t)}\left\{\frac{(1-\alpha-\beta)(1-u_t)H'(u_t)}{\alpha\beta\{H(u_t)-(1-u_t)H'(u_t)\}}-1\right\}.$$

We analyze the equilibrium around a balanced-growth path in which k_t, h_t, and c_t grow at the same rate. Substituting $u_{t+1}=u_t=u$ and $n_{t+1}=n_t=n$ into (3-18) and rearranging the terms, we finally obtain

(3-19) $$\frac{H(u)}{(1-u)H'(u)}=\frac{(1-\alpha-\beta)(1+n)}{\beta(1+\rho)}+1.$$

The L.H.S. is increasing, and approaches zero as $u\to 0$ and infinity as $u\to 1$. There exists a unique value of *u* in the interval (0,1) satisfying (3-19). It is straightforward to derive that k_t, h_t, and c_t grow at the same rate. In the balanced-growth path, per-worker output, per-worker consumption, physical capital, and human capital grow at rate $H(u)$, which is increasing in investment in human capital (e.g., Lucas (1988))).

Our main concern is to investigate a causal link between the labor market aging and per-worker income growth. We obtain the main finding from investigating (3-19). Assuming a once-and-for-all decline in the population growth rate, the advance of the labor force aging, captured by a decline in the population growth rate, leads to a reduction in investment in human capital and as a result deters economic growth.

The economic reasoning behind this finding is stark. From (3-2) and (3-3), we obtain the "wage (rate) profile" as

(3-21) $$\frac{w^o}{w^y} = \frac{(1-\alpha-\beta)(1+n)(1-u)H(u)}{\beta},$$

which is increasing in the population growth rate, given u. A rise in the young workers share in the working population leads to a rise in the relative wage rate of young to elder. Facing it, young people find it beneficial to invest less in human capital and supply more labor, which eventually discourages per-capita income growth.[2] A decline in the young cohort weakens the pressure for competition for good jobs, which is reflected in the rise in the relative wage rate, and motivates young people to make less effort to acquire skills for getting future higher salaries. In the aged society with abundant elder and scarce young, young people take the "myopic" behavior in investment in human capital due to the adverse incentive effect for earning future higher salaries.

Rigorously, as suggested by (3-18), this finding comes from a combination of two different effects. From (3-18) we implicitly derive

(3-20) $$u_t = \phi(u_{t+1}; n_t, n_{t+1}),$$

with $\partial\phi(.)/\partial u_{t+1} > 0$, $\partial\phi(.)/\partial n_t > 0$, and $\partial\phi(.)/\partial n_{t+1} > 0$ at $u_{t+1} = u_t \equiv u$ and $n_{t+1} = n_t \equiv n$. The current and the future population growth rates have positive but different qualitative effects on the current investment in human capital. In the face of the decline in the current population growth rate, young people find it beneficial to invest less in human capital because the wage rate of young workers tends to be high, ($\partial\phi(.)/\partial n_t > 0$). Additionally, in the expectation of the decline in the future population growth rate, they also find it beneficial to invest less in human capital because the wage rate of them as elder workers tends to be low,

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[2] The resulting decline in u in response to a decline in n would increase the supply of young human capital, and tends to lead to a rise in w^o/w^y. However, this indirect effect is too small to offset the direct effect.

($\partial\phi(.)/\partial n_{t+1} > 0$). These two effects are reinforcing.

This nature leads to different effects according to whether the demographic shock is either temporary or persistent, or either anticipated or unanticipated. Consider, for example, the effect of a baby bust (or baby boom) which is captured by a one-time change in the population growth rate. In the face of the decline (or rise) in the current population growth rate, people find it beneficial to invest less (or more) in human capital, but if they accurately expect this shock to be temporary, they do not expect the wage rate of them as elder workers to be low (or high), and hence the adverse effect is limited. When the shock is persistent, the effect is greater to the extent that the shock is anticipated, while when the shock is temporary, the effect is conversely greater to the extent that the shock is unanticipated.

Literally interpreting the model, the level of human capital of young workers should be greater than that of elder workers. The determinants of the relative magnitude are more complex. For one thing, it depends on the value of δ, the extent of inheritance of human capital (equation(2-3)), and for another thing, on the effect of the adoption of new technology on the quality of the existing human capital. A drastic technological change might make the human capital of elder workers rapidly obsolete (e.g. Hobjn and Jovanovich (2001)).

One may wonder whether the positive link between population and economic growth through the labor market channel is dependent entirely on the fact that the cross-partial derivative between young and old human capital is positive, as is keen in the Cobb-Douglas production function. In order to see the robustness of the main finding, we examine a more general production function. In doing so, we consider the following quasi-CES production function;

(3-22) $$Y_t = AK_t^{\alpha}\left\{\frac{\beta}{1-\alpha}\left[(1-u_t)h_t^y N_t\right]^{1-\sigma} + \frac{1-\alpha-\beta}{1-\alpha}\left[h_t^o N_{t-1}\right]^{1-\sigma}\right\}^{\frac{1-\alpha}{1-\sigma}}, \quad \sigma \geq 0 .$$

where σ, the reciprocal of the elasticity of substitution between young and elder workers, represents the degree of substitutability.[3] A smaller σ implies stronger substitutability, which may correspond to Angle-Saxon countries. Except for the case that σ approaches 0, young and

[3] σ in (4-1) is equal to 1-γ in the production function given in footnote 10.

elder human capital are imperfect substitutes, including two special cases: when $\sigma \to 1$, the Cobb-Douglas case as in (2-4) and when $\sigma \to +\infty$, a fixed-proportions technology between two types of workers.

Note that the cross-partial derivative between young and old human capital may be positive or negative, depending on the sign of $(\sigma - \alpha)$, such that

(3-23) $$\frac{\partial^2 Y_t}{\partial\{(1-u_t)h_t^y N_t\}\partial\{h_t^o N_{t-1}\}} = (\sigma - \alpha)\frac{A\beta(1-\alpha-\beta)}{1-\alpha}\left[(1-u_t)h_t^y N_t\right]^{1-\sigma}\left[h_t^o N_{t-1}\right]^{1-\sigma}$$

$$*\left\{\frac{\beta}{1-\alpha}\left[(1-u_t)h_t^y N_t\right]^{1-\sigma} + \frac{1-\alpha-\beta}{1-\alpha}\left[h_t^o N_{t-1}\right]^{1-\sigma}\right\}^{\frac{1-\alpha}{1-\sigma}-1}$$ [4]

With the production function given by (3-22), however, we derive the counterpart of (3-12) as

(3-24) $$\frac{H(u)}{(1-u)^{\sigma}H'(u)} = \frac{(1-\alpha-\beta)(1+n)^{\sigma}}{\beta(1+\rho)} + 1.$$

We obtain two remarkable features. First, when σ approaches 0, u is independent of n. The positive link between population and economic growth through the labor market channel disappears when young and elder workers are perfect substitutes. Secondly, unless $\sigma = 0$ holds, u is always increasing in n, irrespective of the sign of the cross-partial derivative. The labor market channel works so long as human capital of young and elder are *not* perfect substitutes.

Equation (3-23) represents that a decrease in the young workers relative to elder workers (i.e., aging in the labor force) reduces the marginal productivity of elder workers when $\sigma > \alpha$, while it raises the marginal productivity of elder workers when $\sigma < \alpha$. However, we can show that the relative wage rate w^y / w^o is inversely related to the population growth rate irrespective of the sign of the cross-partial derivative. This implies that the sign of the cross-partial derivative sign may have an effect but is not a dominant factor to derive the positive link.

Contrary to the prediction of the standard neoclassical growth theory, an increase in population growth promotes economic growth. Srinivasan and Robinson (1997, p1268) argue

[4] It is immediate that the sign of cross-partial derivative is always positive for the standard CES case.

the positive correlation by assuming that the growth of per-capita human capital is an increasing function of the growth of the aggregate employment. Our model can be interpreted to provide one micro-foundation behind their setting. Jones (1998) constructs a R&D-based growth model in which a more populous economy leads to a richer economy by focusing on the nonrivalrous nature of ideas. The economic implication can be reconciled with that of the R&D-based growth model in its spirit. New ideas, inventions, and new methods for improving productivity could be more produced in a society where young are so vigorous that they devote more resource in investing themselves.

4. Empirical Evidence

In the theoretical part we developed a theoretical mechanism behind which a decline in the share of young workers in the working population deters the subsequent growth of per-worker income. The purpose of this section is to investigate whether the cross-country data will support our hypothesis. Before proceeding to the estimation, we state data used in the regressions.

For the measure capturing the young's incentive effect of investing in themselves, we use the population share of each age group in the total working population, which is available from an *International Labor Office* database (web site; http://laborsta.ilo.org/). Let ACTxxyy denote the population share of workers aged xx to yy at the starting year. In dividing the working population into the two age groups, let ACT2544 denote the share of young workers and let ACT45OVER denote the share of elder workers in the working population. A decline in the value of ACT2544 than the previous decade will, for example, capture the advance of the labor force aging. The coefficient of ACT2544 is expected to be positive, and that of ACT45OVER be negative. Following the theoretical finding, if the labor markets are well organized in the listed countries, the relative wage of young to elder workers might be a better measure. But we do not use this approach for two reasons. First, data on wage distribution by ages is available only for small countries. Second, various distortions and regulations inherent in the labor markets may prevent the increased competition in the workplace from being reflected in wages. Even if data on the relative wage is available, the possible simultaneity problem between economic growth and the relative wage could make it necessary to explore appropriate instruments. As the theoretical finding points out, the share of each age group in the total working population could become a good candidate for instruments.

Additionally, as another aging variable, we use the population share of the total population aged 14 and under at the starting year, denoted POP14. While ACTxxyy is meant to capture the effect of the size of the current generation on investment in human capital, POP14 is meant to capture the effect of the size of the next generation on investment of the current generation. The coefficient of POP14 is expected to be positive.

We conduct cross-country growth regressions using OLS estimates with the pooled data for OECD countries. Our sample includes 22 countries and 4 periods, 1965-1974, 1975-1984, 1985-1994, and 1995-2003.

We begin by regressing per worker GDP growth (GROWTH) on the log of initial per worker GDP level (GDP) and the initial stock of human capital variable (HUMAN). Notice that the GDP variables are measured in terms of *per worker* term, but not of *per capita* term. This is intended to eliminate the possible effect of demographic transition coming from an increasing ratio of the working to the non-working people. The stock of human capital is measured by the average years of school attainment at secondary and higher levels of a population group aged 15 and older. The school-attainment data are available from the web site of Center for International Development at Harvard University (web site; http://www.cid.harvard.edu/ciddata/ciddata.html.)

In column 1 of Table 1, we present the simple regression. The initial level of per worker income is negative and significant, and the initial stock of human capital is positive but insignificant. We control for decade dummies distinguishing between four periods, 1975-1984, 1985-1994, 1995-2003 all the regressions. Numbers in parentheses are based on the White's heteroscedasticity-consistent covariance matrix in all the regressions.

In column 2 we add the aging variable ACT2544. ACT2544 is positive and significant. This finding shows that the greater is the population share of workers aged 25 to 44, the higher is the subsequent per-worker GDP growth, which is consistent with our theoretical finding. The human capital variable is positive and significant at 10% level. We tried other school attainment variables, including ratios of school attainment at secondary and higher levels and average years of school attainment at higher level. The finding is robust in using any of human capital variables listed here.

In column 3 we add another aging variable POP14. POP14 is positive and significant at about 10% level. There emerges a positive effect of a size of the next generation on the subsequent growth, as will be suggested by the theoretical finding. A decreased number of children can lead to a decline in economic growth.

We regressed the human capital variable on the possible its determinants, including ACT2544, POP14, and GDP, but none of them except for GDP was significant.

In column 4 we check the robustness by controlling for two demographic variables, the population growth rate, denoted by POPG, and the growth rate of the working population, denoted by WOKG. The result remains unchanged even controlling for these variables. The coefficient of ACT2544 is 0.081, which implies that one percent change in the population share of workers aged 24 to 44 leads to a change in the annual growth rate of about 0.08%.

In column 5 we replace ACT2544 by ACT45over. ACT45OVER is negative and significant. The interpretation needs comments. As the theory suggests, an increased size of elder workers can have a negative impact on investment in human capital by young people because it weakens the young’s incentive for human capital through the route of a looser wage profile. An increased size of elder workers who are less able to have access to new knowledge and technology has a negative effect on the subsequent growth. Anyway, this finding may support our theoretical hypothesis that young human capital contributes more to growth than elder onr.

In column 6 through 12, we use the aging variable covering the 10 year interval, including ACT2534, ACT3544, ACT4554, ACT5564, and ACT65OVER, respectively. ACT2534 is positive and significant, neither ACT3544 nor ACT4554 is significant, and ACT55OVER is negative and may be significant. An important finding is that people seem to accumulate more human capital in the former half period of age 25-44 than the latter one. Many papers in the labor economics report that wages increase most rapidly in the first 10 years after school education (e.g. Mincer, and others). This finding suggests that the effect of human capital on growth arise not only through formal education, but also through trainings and educations in the workplace.

The results show that as age gets older, the contribution to the subsequent growth is smaller, and is even negative beyond 45. This finding also suggests that our age variables do not capture the demand effect because, if the positive coefficient of ACT2544 captures the consumption boom in the middle age, the coefficient of ACT3544 should be strongly positive.

Some readers might wonder if the positive and significant coefficients of ACT2544 or ACT2534 may simply capture a high proportion of workers who are earning growing salaries. Note that that effect, if it exists, is the effect of demographic transition that does not last long for any one country. Kotlikoff and Gokhale (1992) find evidence showing that the labor productivity grows until forties in the U.S. data.

In order to provide more persuasive interpretation on the above finding, we explore an alternative measure that will influence the young's incentive for increasing human capital and may complement ACT2544 or ACT2534.

We use an "unemployment rate" as another variable to capture the young's incentive effect, although there never emerges unemployment in the theoretical model. In recent decades, in many OECD countries young people face difficulty in finding jobs. The unemployment rate of young workers is far higher than the country's average in many OECD countries. Although the high unemployment rate may be a result of economic stagnation, it is conversely expected to play a disciplinary role in inducing young people to invent in themselves for good jobs, following the notion of the efficiency wage hypothesis (e.g. Shapiro and Stiglitz (1984) and Akerlof and Yellen (1981)).

Before proceeding to the main regression, we check the correlation between the school enrollment rate and the unemployment rate in order to examine whether the unemployment rate can be used for the variable capturing the incentive effect. Table X shows the results. In column 1(equation 10), the coefficient of UR is positive and significant. This result suggests that a high unemployment rate tends to work to play a disciplinary for young people in spending more time on education. In column 2(equation11), the coefficient of ACT2544 is also positive and significant. These two finding jointly suggest that, ACT2544 and UR are both variables that capture the young's incentive for investing in human capital and may complement with each other.

In Figure Y we report the result of the growth regression. In column 1(column17) the coefficient of UR is positive and weekly significant. In column 2(equation19), ACT2544 and POP14 enter as additional variables. The coefficient of UR is again positive and weekly significant. ACT2544 and POP14 remain positive and significant, but the sensitivity of ACT2544 declines by including UR. This result may reflect the complementary role of UR and ACT2544 in the regression. In column 3 through 6, aging variable covering the 10 year interval enters, jointly with UR. The result of each aging variable remains unchanged by including UR. Note that when the coefficient of the aging variable is insignificant or negative, the statistical significance of UR increases. For example, in column 5 (equation23), the coefficient of UR is significant. The overall result is consistent with the hypothesis that ACT2544 and UR are both variables that capture the young's incentive for investing in human capital.

Figure 2 illustrates the time series of the population share of workers age 25 to 34 in the average of OECD countries, Japan, U.S.A, and the average of European countries. Except for Japan, the population share of workers age 25 to 34 increase over time. Surprisingly, even in Europe, it increases up to 1990s although the aging population advances in many of European countries. Migration might explain this seemingly contradictory observation.

The behavior of labor migration can become an instrument to identify a theoretical mechanism through which the labor force aging influences economic growth. If the positive coefficient of the share of young age group only captures a high proportion of workers whose labor productivity grows faster, the inflow of migration could lead to a slowdown of economic growth because it deteriorate the average level of human capital. On the other hand, if it captures the "incentive effect", the inflow of migration can be consistent with promoting economic growth. The evidence in Europe may suggest the latter channel.

The empirical finding may have a few comments on the "Lost Decade" in Japan. At 1990, ACT2534, ACT3544, ACT4554, ACT5564, and ACT65OVER are 19.2%, 25.0%, 21.9%, 14.7%, and 5.8%, while those of the average values in OECD countries are 27.1%, 25.2%, 18.4%, 9.7%, and 1.8%&, respectively. The age distribution in Japan is obviously skewed to elder ages. Compared to the average, the smaller share of workers aged 25 to 34 leads to a decline in the annual per worker growth rate by (27.1%-19.1%)×0.111=0.89%, and moreover the greater share of workers aged 55 to 64 may leads to a decline in the annual per worker growth rate by (14.7%-9.7%)×0.069=0.35%. These figures reveal that the skewed age distribution in the labor market can explain significant part of sources of the lost decade.

Finally, we report the prediction of per worker GDP growth in the feature although the estimation is made based on the regression in earlier version and so a little different from figures of the results here. Table 2 provides the result. It reports that Greece, Portugal, and Spain will experience relatively high growth in per worker GDP, while the growth rate in the United States will decline over the next two decades in statistically significant levels. The growth rate for 2010-2020 will be smaller than the one for 2000-2010 in all countries except for Ireland.

5. Discussion

Departure from the "Age-Dependent" Society

Thus far we have argued on the premise that the society is highly "age-dependent". In this section we relax this restriction by allowing for elder workers to compete with young workers in the labor market.

We have assumed that all the agents get promoted when they are old. However, this situation is not true in the actual society, and pronounced in the aged society with a greater number of elder workers relative to young workers. In the actual labor market some elder workers have to compete with young workers. In order to capture this situation, assume that any of young workers is employed as a skilled worker with the probability π when he or she is old. It turns out that the remaining fraction $1-\pi$ of old agents fails in promotion and remain to be employed as unskilled.

The promotion probability π is supposed to depend on several factors, including firm growth, nature of internal organization, and demographic factors. In terms of the concern in this paper, the relationship between the population growth and the promotion probability may be worthwhile investigating. For example, an agent of a baby boom generation may evaluate their promotion probability to be low because they find themselves to face severe competitive environments for promotion. Although we admit the possible impact of the demographic factors on the promotion rate, their links are supposed to be complicated. Thus we investigate the effect of the "exogenous" change in the promotion rate on the aggregate economy and pursue implications of the effect of the aged society.

In order to focus on the effects of a change in the mobility of the labor market, we abstract from the effects of uncertainty about the future wage income. Consider the existence of life insurance companies that behave competitively. With the assumption that administrate costs per contract are negligible, payments are made on an actuarially fair basis. Letting $\overline{w}_{t+1}$ denote the wage rate that agents receive in the second period of life, we obtain $\overline{w}_{t+1} = \pi w_{t+1}^{o} + (1-\pi) w_{t+1}^{y}$.

Investment in human capital is eventually determined to satisfy

(4-1) $$\frac{(1+\rho)\beta H(u)}{H'(u)} = (1-\alpha-\beta)(1+n)(1-u) + (1-\alpha)(1-\pi).$$

Compared to (3-20), you will find that the marginal effect of a change in the population growth rate on investment in human capital is qualitatively the same irrespective of the promotion probability.

We are now ready to investigating the effect of a change in the promotion probability on the investment in human capital. There are potentially offsetting effects of a rise in the promotion probability. On one hand, a rise in the promotion probability tends to encourage young people to invest in human capital. On the other hand, it tends to increase a population share of skilled relative to unskilled workers, driving down the relative wage rate of elder workers, which conversely tends to provide a disincentive for them to invest in human capital. A simple calculation of (4-1) implies that the latter effect always dominates the former effect; the more severe is the competition among workers of different generations in the sense that people find difficulty in getting promotion, the faster the economy grows. When Confucianism is dominant, the elder are respected, and the occupational position is "age-dependent", the economy tends to be stagnant.

We are now in a position to discuss the indirect effect of an advance in the labor force aging through the change in the promotion probability. An agent of a baby bust generation, in the faced of the less competitive environment for promotion, may invest less in human capital. If he expects that the baby bust will go on until the next generation, he may conversely expect that his promotion probability is low because the organization to which he belongs is predicted to shrink. However, if the promotion probability has inertia as the efficiency wage hypothesis suggests, he may evaluate his promotion probability not to decline so much. When the promotion probability does not decline even in the aged society, investment in human capital declines and the economic growth goes down.[5]

Migration and Economic Growth

Typical human-capital-based growth models could predict a negative impact of labor migration on economic growth. Migrant workers tend to possess the lower level of human capital than people of the host country, and so the inflow of migration could deteriorate the average level of human capital and deter economic growth of the host country (e.g., Lucas (1988))

The developed model provides an alternative channel through which migration influences economic growth. Assume that there is a once-and-for-all flow of migration of young workers with the size of mN_t to the host country at each period t. Migrants are endowed with σh_t^y units of human capital and have access to the technology available in the host country. Empirical observation shows that in the U.S. the average skill of migrant workers is less than that of domestic workers. Typically, we have in mind the case for $\sigma < 1$. They work as unskilled workers in the first period of life and consume in the second period of life. The preference of the migrant worker is given by $V_t = \rho \log c_{t+1} + \rho(1+n^m)V_{t+1}$, where n^m is the population growth rate of the migrant worker. For analytical simplicity, migrant workers are assumed to go back to their home country after two periods and die.

Here the sum of human capital supplied by domestic young workers and migrant workers is

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[5] Ariga *et al*(1992) and Brunello *et al*(1995) investigate the relationship among corporate hierarchy, promotion, and firm growth from the prospect of incentive approach.

$(1-u_t)N_t h_t^y + \sigma m N_t h_t^y$. Wage rates are given by

(4-2) $$w_t^y = \beta A\left(\frac{k_t}{h_t^o}\right)^{\alpha}\left(1+\sigma m-u_t\right)^{\beta-1}\left(1+n\right)^{\beta-1}(2+n)^{\alpha},$$

(4-3) $$w_t^o = \left(1-\alpha-\beta\right)A\left(\frac{k_t}{h_t^o}\right)^{\alpha}\left(1+\sigma m-u_t\right)^{\beta}\left(1+n\right)^{\beta}(2+n)^{\alpha}.$$

Investment in human capital is eventually determined to satisfy

(4-4) $$\frac{\beta H(u)}{\rho H'(u)} = (1+n)(1-\alpha-\beta)(1+\sigma m-u).$$

An increase in the migration, captured by an increase in *m,* raises investment in human capital made by people of the host country, which eventually promotes economic growth. As will typically be the case, the migration increases the labor supply of unskilled workers relative to skilled workers, driving down the wage rate of young workers, which in turn provides an incentive for the domestic young agents to invest more in human capital. The change in the share of unskilled workers as the total working population in the host country, on the one hand, gives the short-run negative externality to young workers of the host country through the change in the relative wages, but on the other hand gives the long-run positive externality through the enhancement of growth.[6]

Labor migration tends to deteriorate the average level of human capital, but enhances economic growth. This finding is contrasted with several human-capital-based growth theories that take the average level of human capital as an engine of economic growth (e.g., Lucas (1988)).

[6] We obtain the same qualitative result assuming that there is a one time labor migration and migrant workers live in the host country. Then the growth rate of the migrants should be the same as the one of the host country.

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Figure 1-a: Share of workers aged 20-39 to all workers (G7-countries)

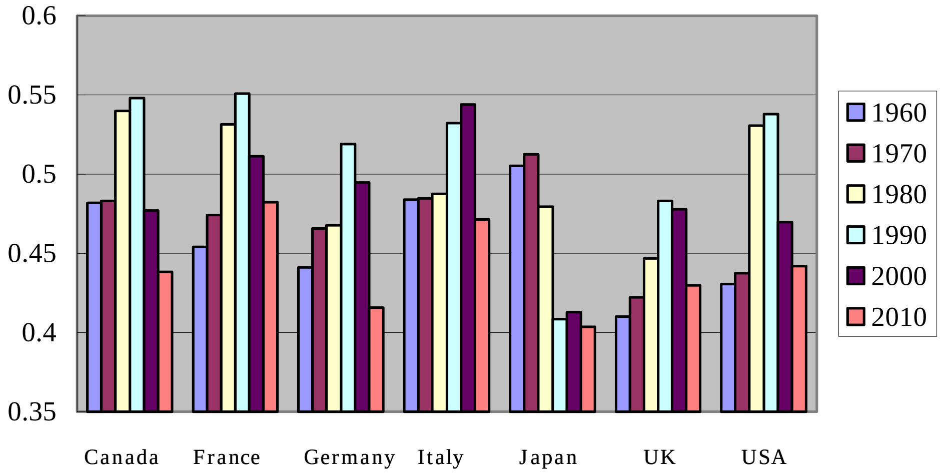

Figure 1-b: Share of workers aged 20-39 to all workers (OECD countries)

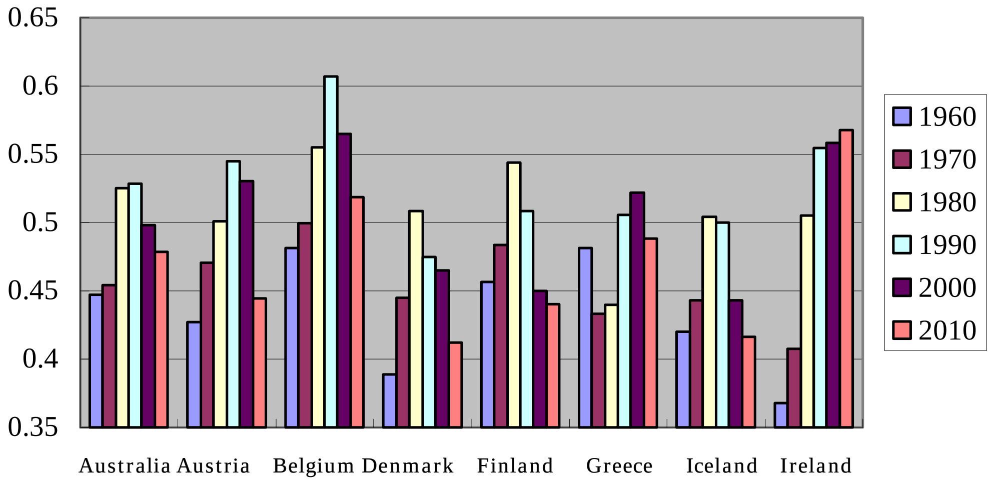

Figure 1-c: Share of workers aged 20-39 to all workers (OECD countries)

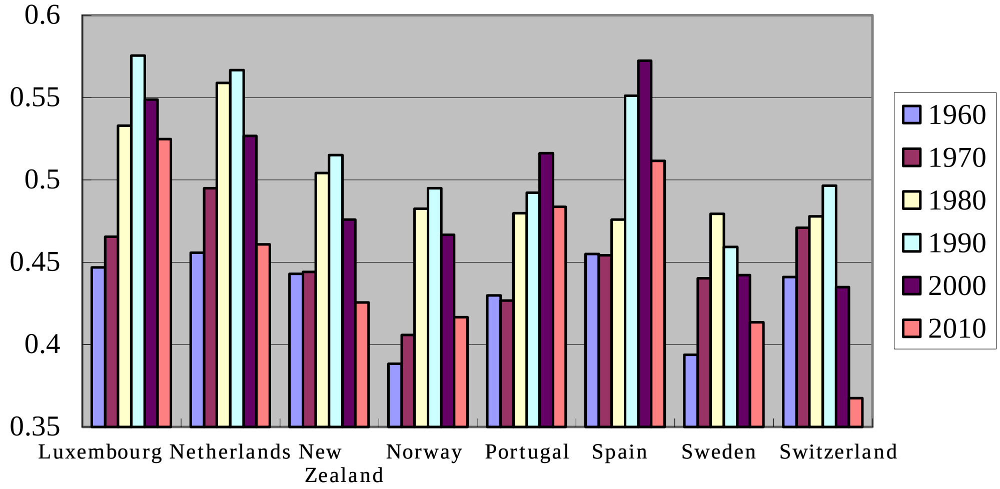

Figure 2 Share of workers aged 25-34

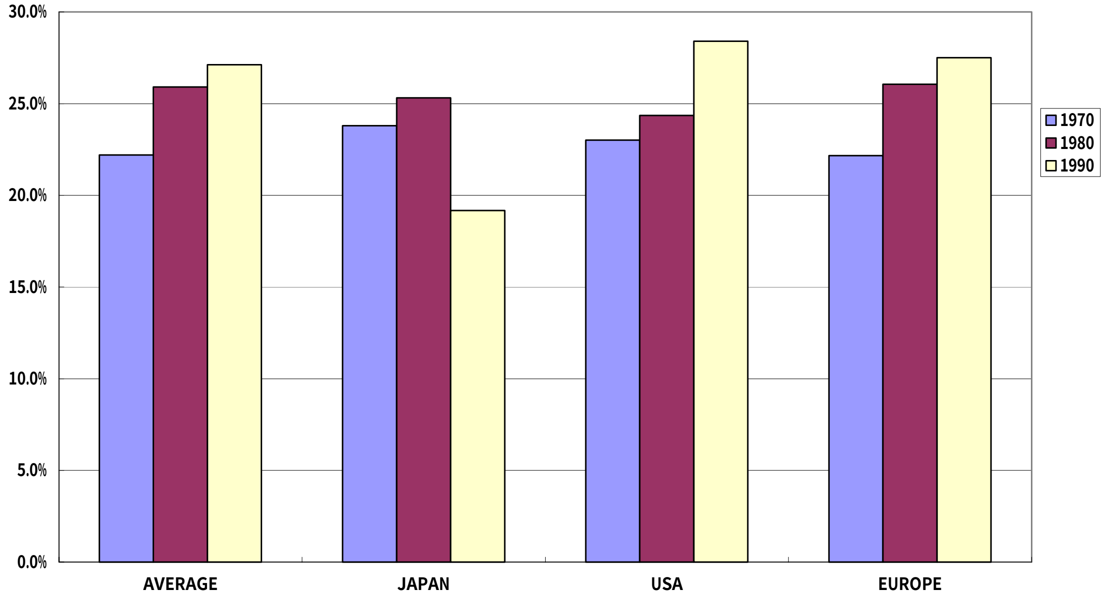

Table 1: Growth and Labor Force Aging

Dependent variable: Per worker GDP growth

	1	2	3	4	5	6
constant	1.397	1.381	1.376	1.176	1.422	1.393
	(29.08)	(35.97)	(35.58)	(5.585)	(32.79)	(28.42)
log of initial income per	-0.036	-0.038	-0.039	-0.037	-0.037	-0.037
worker **(GDP)**	(-7.377)	(-10.36)	(-10.56)	(-8.916)	(-8.649)	(-7.050)
secondary and higher	0.001	0.002	0.002	0.001	0.001	0.001
schooling years(**HUMAN**	(0.981)	(1.784)	(1.640)	(1.443)	(0.879)	(0.856)
share of workers aged		0.096	0.090	0.081		
25-44(**ACT2544)**		(3.221)	(3.003)	(2.731)		
share of workers aged 45					-0.082	
and over (**ACT45OVER)**					(-3.463)	
share of workers aged						0.019
15-24(**ACT1524)**						(0.337)
share of population aged			0.029	0.029	0.038	0.034
0-14(**POP14)**			(1.617)	(1.624)	(1.819)	(1.094)
Population growth**(POPG**				0.590		
				(0.217)		
working population				-0.403		0.002
growth (**WOKG)**				(-1.715)		(0.045)
no. of observations	88	88	88	88	88	88
Adj. R2	0.637	0.681	0.684	0.692	0.688	0.640

Note: Each data is pooled decade for four periods: 1960-1970, 1970-1980, 1980-1990, and 1990-2000. Numbers in parentheses are t-values based on the White's heteroscedasticity-consistent covariance matrix. Results for decade dummies are deleted.

Table 1: Growth and Labor Force Aging (Continued)

Dependent variable: Per worker GDP growth

	7	8	9	10	11	12
constant	1.397	1.381	1.376	1.176	1.422	1.406
	(35.47)	(35.97)	(35.58)	(5.585)	(31.25)	(35.65)
log of initial income per	-0.040	-0.038	-0.039	-0.037	-0.040	-0.039
worker **(GDP)**	(-90910)	(-10.36)	(-10.56)	(-8.916)	(-8.779)	(-9.616)
secondary and higher	0.001	0.001	0.000	0.001	0.001	0.001
schooling years**(HUMAN**	(1.622)	(1.178)	(0.370)	(0.978)	(1.287)	(1.489)
share of workers aged	0.143					0.111
25-34(**ACT2534)**	(4.443)					(2.731)
share of workers aged		0.108				
35-44(**ACT3544)**		(1.225)				
share of workers aged			-0.111			
45-54(**ACT4554)**			(-1.754)			
share of workers aged				-1.319		-0.069
55-64(**ACT5564)**				(-3.396)		(-1.485)
share of workers aged 65					-1.233	
and over(**ACT65OVER)**					(-1.652)	
share of population aged	0.028	0.036	0.044	0.037	0.036	0.034
0-14(**POP14)**	(1.502)	(1.857)	(1.979)	(1.836)	(1.778)	(1.094)
no. of observations	88	88	88	88	88	88
Adj. R2	0.685	0.661	0.662	0.671	0.653	0.687

Note: Each data is pooled decade for four periods: 1960-1970, 1970-1980, 1980-1990, and 1990-2000. Numbers in parentheses are t-values based on the White's heteroscedasticity-consistent covariance matrix. Results for decade dummies are deleted.

Table 2: Estimation of Per Worker GDP Growth for 2000-2010 and 2010-2020

GDP per worker growth	1990-2000	2000-2010 (Estimated)	2010-2020 (Estimated)
Australia	2.36%	0.42%	0.08%
	(0.735)	(-0.344)	(0.221)
Austria	1.32%	1.01%	-0.42%
	(-0.299)	(0.304)	(-0.686)
Belgium	1.15%	1.21%	0.13%
	(-0.464)	(0.522)	(0.308)
Canada	1.28%	0.19%	-0.30%
	(-0.335)	(-0.607)	(-0.471)
Denmark	2.01%	0.20%	-0.56%
	(0.391)	(-0.592)	(-0.933)
Finland	1.59%	0.27%	0.06%
	(-0.025)	(-0.520)	(0.184)
France	0.79%	1.14%	0.32%
	(-0.831)	(0.447)	(0.648)
Germany	1.14%	1.03%	-0.32%
	(-0.474)	(0.326)	(-0.504)
Greece	1.40%	2.58%	1.15%
	(-0.222)	(2.039)	(2.127)
Iceland	1.45%	0.37%	0.00%
	(-0.170)	(-0.402)	(0.070)
Ireland	4.39%	0.37%	0.45%
	(2.769)	(-0.401)	(0.881)
Italy	0.79%	1.07%	-0.25%
	(-0.829)	(0.371)	(-0.377)

Japan	0.61%	0.96%	0.50%
	(-1.006)	(0.246)	(0.959)
Luxembourg	4.15%	-1.57%	-1.24%
	(2.524)	(-2.556)	(-2.148)
Netherlands	2.00%	0.88%	-0.29%
	(0.385)	(0.156)	(-0.458)
New Zealand	1.12%	1.27%	0.14%
	(-0.500)	(0.598)	(0.317)
Norway	2.44%	0.10%	-0.55%
	(0.820)	(-0.708)	(-0.913)
Portugal	1.94%	2.40%	1.09%
	(0.321)	(1.842)	(2.033)
Spain	1.28%	2.21%	0.62%
	(-0.341)	(1.631)	(1.173)
Sweden	1.01%	0.51%	-0.06%
	(-0.607)	(-0.254)	(-0.044)
Switzerland	-0.26%	0.17%	-0.70%
	(-1.870)	(-0.624)	(-1.193)
United Kingdom	1.63%	0.86%	-0.02%
	(0.014)	(0.136)	(0.039)
United States	1.63%	-0.72%	-0.73%
	(0.015)	(-1.612)	(-1.235)
Average	1.62%	0.73%	-0.04%
Standard Deviation	0.010	0.009	0.006

Note: Numbers in parentheses are normalized values of which mean is zero and standard deviation is one, which represents how significant these values are from each decade average value.