Population Aging, Economic Growth, and the Importance of Capital

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Abstract

This paper argues that the impact on economic growth from the on-going demographic transition in the population age-distribution depends critically on the relative importance of labor versus capital in production. Our key insight is that as the working fraction of the population decreases, output per person does not necessarily fall. Within an Overlapping Generations model with a Cobb-Douglas aggregate production function, population aging can increase output per person, if production is sufficiently capital intensive. Cross-country regressions provide empirical support for our theory.

JEL Classification: E1, E2, J1, O4

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1 Introduction

Mortality and fertility rates within countries have declined over time, and this demographic transition has been nearly universal. In most developed countries, mortality rates among the young fell first, causing a bulge or 'baby-boom' generation, a large cohort followed by a relatively small one. When this baby-boom cohort reached its peak working years, output per-person surged. This so-called 'demographic dividend' is defined by the period of time in which a large share of a country's population is in their working period of life. For many countries, that period has ended and the share of workers in the population is set to decline. Thus, an important question is what happens next for economic growth?

An intuitive guess might be that living standards will fall due to the small share of workers in the population and large dependency ratios. Samuelson (1975) articulated this view. But a decline in output per person is not a foregone conclusion. Mason and Lee (2006) and Lee and Mason (2010) called the potential for continued economic growth a 'second demographic dividend' (although it could be a prolonged effect from the first; see Kuhn and Prettner (2015)). For example, the small cohort might inherit the capital of the baby-boom generation, potentially leading to 'capital deepening' and output growth. Our key insight is that the relative importance of labor versus capital in production is critical for determining how the demographic changes affect future economic growth.

A large literature has focused on the macroeconomic impact of the demographic transition. Lee (2003) provides details on the demographic transition going back 300 years. Also, see Cervellati and Sunde (2011) and Cervellati et al. (2017). Bloom et al. (2001) and Lee and Mason (2006) each give a clear explanation of the demographic dividend. Kelley and Schmidt (1995), Bloom et al. (1999), Bloom and Canning (2006), Lee et al. (2006), Bloom et al. (2007), Bloom et al. (2009), Bloom and Finlay (2009), Bloom et al. (2010), Liao (2011), and Sánchez-Romero (2013), among a great many other papers others, document the (first) demographic dividend across the world. Bairoliya et al. (2017) and Börsch-Supan (2013) are both more forward looking in examining the impact of future population growth. To the best of our knowledge, none of the papers in this vast literature have focused on the relative importance of capital for production, as we do here.

To demonstrate our theory, we consider a reduction in the number of workers within a standard Overlapping Generations model featuring a Cobb-Douglas production function that combines the labor of the working aged with capital to create output. The representative production function mathematically expresses the economy's overall ability to create output from the available inputs (labor and capital). Within this standard economic model, we show that output per person can actually increase as the number of workers declines, as long as the production process is sufficiently capital intensive. The implications from the model are theoretical, but we conclude by showing that regression-based empirical evidence from a panel of countries supports our theory.

2 A Model of Population Aging and Production

We first lay out a simple discrete-time Overlapping Generations model economy, and then we show how demographic changes affect output.

Demographics During each period, three generations (children, workers, and retirees) coexist, but the cohort sizes may differ. The population demographics evolve exogenously. Let the total number of people alive at time t be denoted N_t, which equals the summation of the $N_{c,t}$ children, $N_{w,t}$ workers, and $N_{o,t}$ retirees. We denote the working fraction of the population as

$$\theta_t \equiv \frac{N_{w,t}}{N_t}. \tag{1}$$

We also define parameter g_t to capture the dynamic motion in θ, such that $\theta_{t+1} = g_t \theta_t$.[1]

[1]Below, we consider a period in which g_t is less than one. Note that g must then increase sometime in the future or θ goes to zero, which does not make sense from a practical point of view.

Households Households make consumption and saving decisions beginning in their working years. Agents within the working cohort at time t maximize utility over current consumption $c_{w,t}$, and during retirement $c_{o,t+1}$. The households face two budget constraints

$$c_{w,t} + s_t \leq w_t \tag{2}$$

$$c_{o,t+1} \leq (1 + r_{t+1})s_t \tag{3}$$

where w is the wage, s is saving, and r is the real interest rate.

If we impose log utility and discount factor β, then utility maximizing households save a constant fraction of their wage:[2]

$$s_t = \frac{\beta}{1+\beta} w_t. \tag{4}$$

Production A nationally representative firm combines capital K and labor N_w to create output Y using a Cobb-Douglas production technology with capital output elasticity $\alpha \in (0, 1)$.[3] All prime age agents work, so aggregate output at time t equals

$$Y_t = K_t^{\alpha} N_{w,t}^{1-\alpha}. \tag{5}$$

Dividing this Equation by the total population, provides an expression for the output per *person* y_t

$$y_t \equiv \frac{Y_t}{N_t} = k_t^{\alpha} \theta_t, \tag{6}$$

where k_t is capital per *worker*. As we show below, the elasticity of capital α is a critical parameter for determining future economic growth; it governs the importance of labor relative to capital in the production function.

The capital stock is determined by the previous generations saving. Capital completely

[2]That is, $\max_{c_{w,t}, c_{o,t+1}} \mathbb{U} = log(c_{w,t}) + \beta log(c_{o,t+1})$ subject to the budget constraints.

[3]We abstract from a total factor productivity term, as it does not affect the interpretation of the results.

depreciates at the end of each period of use.[4] Therefore, the next generation's physical capital stock depends on the number of people in the current working cohort and their per-person gross saving

$$K_{t+1} = N_{w,t} s_t. \tag{7}$$

Setting wages w_t equal to the marginal product of labor, equation (7) can be rewritten using equation (4)

$$K_{t+1} = \frac{\beta}{1+\beta}(1-\alpha) K_t^{\alpha} N_{w,t}^{1-\alpha}, \tag{8}$$

and capital per-worker is

$$k_{t+1} = \frac{K_{t+1}}{N_{w,t+1}} = \frac{\beta}{1+\beta}(1-\alpha) k_t^{\alpha} \frac{N_{w,t}}{N_{w,t+1}} \tag{9}$$

Population Aging and Per-Capita Output This general setup delivers a 'demographic dividend' whereby a fall in fertility (a decline in non-working children, $N_{c,t}$) mechanically increases output per person.[5] Our central question is what happens next? What happens to per-capita output when the fall in fertility eventually results in a decline in the number of prime-age workers ($N_{w,t+1}$)?

We are interested in the specific dynamic population transition that much of the world is currently experiencing (i.e. a smaller birth cohort at time t aging into their working years at time $t+1$ such that $N_{w,t+1} < N_{w,t}$) rather than, say, comparing steady states of two economies with different age structures. Whether output per person continues to increase depends on the relative importance of capital versus labor in the production function. A decrease in the size of the working age cohort (due to lower birth rates) can lead to an increase in per-capita output if the capital share is sufficiently large. If we assume that the total number of dependents ($N_c + N_o$) is fixed, then the impact on y_{t+1} is governed by the

[4] Each period of life represents 20 or more years, so the assumption of full depreciation is not without merit.

[5] We focus on fertility decline because it is the most striking demographic change. See Figure 17 in Doepke and Tertilt (2016), for example.

relationship between θ and the production function parameter α. We state this relationship as Proposition 1 and derive it in the Online Appendix.[6]

Proposition 1 *A decrease in $N_{w,t+1}$ increases y_{t+1}, as long as $\theta_{t+1} > 1 - \alpha$.*

Proposition 1 encapsulates our main point, and the mechanism is as follows. A decline in fertility, resulting in a fall in $N_{w,t+1}$, has two opposing effects on y_{t+1}. First, the fall in θ_{t+1} reduces production because there are fewer workers. Second, the fall in $N_{w,t+1}$ results in capital deepening – an increase in capital per-worker – which increases output per worker.

Whether the decline in θ_{t+1} or the increase in output per worker dominates depends both on the relative size of the working age cohort and the labor share $(1-\alpha)$. On the one hand, if production is sufficiently capital intensive, the higher capital per worker leads to an increase in y_{t+1}, even as $N_{w,t+1}$ falls. On the other hand, if production is relatively labor intensive, then y_{t+1} falls because workers are relatively more important in the production process and there are "too few" of them.

Since the condition in Proposition 1 is not immediately intuitive, it might be worthwhile to think through some examples. First, consider a low value for θ, near zero. Then, since θ_{t+1} is less than $1-\alpha$, a fall in $N_{w,t+1}$ decreases y_{t+1}. The 'lost' workers have a high marginal product. Second, consider a high value for α, near one. Then, workers are not needed for production, only capital is important, and the condition in Proposition 1 always holds. The lost workers have little impact on output; therefore, output per person goes up. A third way to think through the result is to consider how a low value for g (recall $\theta_{t+1} = g\theta_t$) impacts $y_{t+1} = k_t^{\alpha}\theta_t$. For example, a $g_t < 1$ has an obvious negative impact on y through θ, but it can also positively impact capital per worker, k. Clearly, the relative quantitative impact is governed by the importance of capital in the production function (parameter α), as laid out in Proposition 1.

Note, Proposition 1 holds when K_{t+1} does not respond to the decline in $N_{w,t+1}$. Our

[6] The Online Appendix also shows that the same general result holds in a model with a more general production function.

simple log utility function delivers this; however, in reality, capital accumulation may depend on the current and future population age structure.[7] In the Online Appendix, we characterize a general version of Proposition 1 by considering a model where the capital stock, K, is determined by workers' saving decisions, which can change depending on how the demographics evolve. The condition for determining whether a decrease in N_w increases output per capita still depends on the relative size of the θ versus the labor share in this more general model. However, it is also dependent on the elasticity (or sensitivity) of capital accumulation. Estimates for the elasticity of capital (even to its own price) vary greatly in the literature and sometimes include zero. We leave further investigation into the important topic of how the capital stock responds to demographic changes for future research.

3 Empirical Evidence

We have shown theoretically that population aging does not necessarily lead to a reduction in living standards, even within basic economic models. If production relies heavily on capital, there could be a *second demographic dividend*. In a way, this is an old utopian-esque idea: people of the future may not need to work as much because machines and technology will do the production, and the size of the labor force may not be so important. Moreover, as Lee and Mason (2006) point out, if the next phase of economic growth is driven by long-lasting investments, then the second demographic dividend could be less transitory in nature than the first.

For most countries, the baby-boom generations have just begun retiring, but the timing and magnitude of the demographic transitions vary. Therefore, we can use the available data to test our theory empirically.[8] We estimate

$$\Delta log(y_{i,d}) = b_1 \Delta log(N_{i,d}) + b_2 \Delta\theta_{i,d} + b_3 \Delta\theta_{i,d} \times I_{\{\theta>(1-\alpha)\}_{i,d}} + X'_{i,d}\beta + \epsilon_{i,d}, \quad (10)$$

[7]Similarly, in the long-run, the population's demographic structure is likely endogenous to economic conditions. See Greenwood et al. (2017).

[8]Also, see Aksoy et al. (2015).

where the dependent variable is the average growth rate of per-capita gross domestic product (GDP) in country i during decade d; $\Delta log(N_{i,d})$ is the average population growth rate; $\Delta\theta_{i,d}$ is the change in the working fraction of the population, and I is an indicator equal to 1 if the condition in Proposition 1 is met. The labor share data (to measure $1-\alpha$) comes from Karabarbounis and Neiman (2013) and we take the average for each decade. The GDP data comes from the Penn World Tables 9.0, and the population data is from the UN World Population Prospects 2017 Revision. We measure θ as the employment to population ratio in the UN data. The data spans three decades: the 1980s, 1990s, and 2000s, and 21 countries have complete information for at least two decades. About half the countries in the panel meet the condition for Proposition 1 ($I_{i,d} = 1$) at least once. The vector X contains the constant and a full set of year and country dummy variables; ϵ is the error term.

Table 1 reports the results. The OLS estimate of b_3 is -2.08, and it is statistically different from zero at the 10 percent level. Consistent with our theory, a declining population has a positive impact on output per person, if the condition in Proposition 1 is met. The effect is quantitatively large, too. The estimate for b_3 exceeds b_2 (1.05), indicating that 1 percentage point decline in θ corresponds with about a 1 percent increase in y.

Equation (10) includes decade fixed effects to account for global time trends. Column 2 reports the estimates without the fixed effects and the results become stronger. In column 3, we use only the 15 (highly-developed) countries that have data for every year from 1980-2010. The estimate of b_3 (-1.04) is smaller, but it is still statistically significant. We obtain a similar estimate in column 4 using a larger set of countries and averaging over 5-year intervals (rather than decades) spanning back to 1975. We include $\Delta log(N_{i,d})$ in the regressions because Proposition 1 assumes a fixed non-working population share. Dropping this variable strengthens the results in all cases. Column 5 gives an example.

Based on both our theory and the data, we conclude that if production is sufficiently capital intensive, a reduction in the number of workers can increase output per person. Karabarbounis and Neiman (2013) document that the labor share has been decreasing across

Table 1: Regression Estimates of the Effect on Growth

		Independent Variable: Growth in GDP per capita				
		(1)	(2)	(3)	(4)	(5)
		10 Year	10 Year	10 Year	5 Year	5 Year
b_1	$\Delta log(N)$	0.45	0.61	0.95*	-0.53	-
		(0.36)	(0.69)	(0.21)	(0.31)	
b_2	$\Delta\theta$	1.05*	0.96†	0.88**	1.53*	1.54*
		(0.13)	(0.49)	(0.06)	(0.44)	(0.44)
b_3	$\Delta\theta \times I_{\theta > ls}$	-2.08†	-2.58*	-1.04*	-1.03*	-1.19**
		(0.58)	(1.05)	(0.20)	(0.34)	(0.30)
Country Fixed Effects		Yes	Yes	Yes	Yes	Yes
Time Period Fixed Effects		Yes	No	Yes	Yes	Yes
R^2		0.86	0.78	0.90	0.63	0.62
Countries		21	21	15	64	64
Observations		57	57	45	236	236

Notes: This table reports the coefficient estimates based on Equation (10). Standard errors in parenthesis. Stars denote statistical significance at the $^{\dagger}p < 0.10$; $^{*}p < 0.05$; $^{**}p < 0.01$ level based on robust standard errors clustered by the 5 or 10 year time-period.

the world. As countries progress through their demographic transition and become older, the decline in the labor share (to the extent that it reflects the underlying production technology) could make it more likely that the condition in Proposition 1 holds. Technological change and capital accumulation will, of course, matter, too. However, it is not a foregone conclusion that population aging will reduce living standards.

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