

Population Aging, Economic Growth, and the Importance of Capital

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September 28, 2018

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 share of the population decreases, output per person does not necessarily fall. Within a simple model of aggregate production, 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

Keywords: Demographics, Population Aging, Economic Growth, Labor Share, Fertility

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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 Prettnner \(2015\)](#)). 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 (due to population aging) within an aggregate 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 can 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

Demographics The population demographics evolve exogenously. The total number of people alive at time t is N_t , with the working age subset, $N_{w,t}$, inelastically supplying labor.

The working share ws is

$$ws_t = \frac{N_{w,t}}{N_t}. \quad (1)$$

Production A representative firm combines capital K and labor N_w to create output using a constant returns to scale technology, represented by production function, $F(K, N_w)$.

For simplicity, we abstract from a total factor productivity term (i.e. technology growth).

Output per person at time t equals

$$y_t = \frac{F(K_t, N_{w,t})}{N_t}. \quad (2)$$

Allowing for perfectly competitive markets, capital and labor are paid their marginal products. So, the share of output due to capital is $\frac{F_K(K_t, N_{w,t})K_t}{F(K_t, N_{w,t})}$, where F_K stands for the

partial derivative of output with respect to a change in the capital input. Therefore, the labor share is

$$ls_t = 1 - \frac{F_K(K_t, N_{w,t})K_t}{F(K_t, N_{w,t})}. \quad (3)$$

The factor shares are critical for determining future economic growth in the face of demographic change; they govern the relative importance of capital versus labor in production.

Population Aging and Per-Capita Output This general setup delivers a ‘demographic dividend’ whereby a fall in fertility (or a decline in non-working children) mechanically increases output per person.¹ 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 ($N_{w,t+1}$)?

Whether output per person continues to increase for future generations 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 sustained lower birth rates) can lead to an increase in per-capita output if the capital share is sufficiently large.

Consider a 1 percent decline in $N_{w,t+1}$. Also, assume for the moment that K_{t+1} does not respond to this decline.² Then, total output declines by ls_{t+1} percent. The population declines by $\frac{N_{w,t+1}}{N_{t+1}} = ws_{t+1}$ percent (holding the number of non-workers constant). Hence, if ws_{t+1} exceeds ls_{t+1} , output per person increases. The impact on y_{t+1} boils down to this simple relationship, which we state as Proposition 1 and derive in the Online Appendix.

Proposition 1 *A decrease in $N_{w,t+1}$ increases y_{t+1} , as long as $ws_{t+1} > ls_{t+1}$.*

Proposition 1 encapsulates our main point, and the intuition 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 ws_{t+1}

¹We focus on fertility decline because it is the most striking demographic change. See Figure 17 in [Doepke and Tertilt \(2016\)](#), for example.

²The Online Appendix provides an example of this, where K_{t+1} is determined by the saving decisions of workers with log utility.

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 ws_{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. On 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.

Proposition 1 holds when K_{t+1} does not respond to the decline in $N_{w,t+1}$. This, however, may not always be the case.³ In the Online Appendix, we characterize a general version of Proposition 1 by considering a model in which 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 ws_{t+1} increases output per capita still depends on the relative size of the working share 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](#)

³Similarly, in the long-run, the population’s demographic structure is likely endogenous to economic conditions. See [Greenwood et al. \(2017\)](#).

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.⁴ We estimate

$$\Delta \log(y_{i,d}) = b_1 \Delta \log(N_{i,d}) + b_2 \Delta ws_{i,d} + b_3 \Delta ws_{i,d} \times I_{\{ws > ls\}_{i,d}} + X'_{i,d} \beta + \epsilon_{i,d}, \quad (4)$$

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; $\Delta ws_{i,d}$ is the change in the working share, and I is an indicator equal to 1 if the condition in Proposition 1 is met. The labor share data 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 define ws as the employment to population ratio. 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 ws corresponds with about a 1 percent increase in y .

Equation (4) 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

⁴Also, see Aksoy et al. (2015).

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 (0.36)	0.61 (0.69)	0.95* (0.21)	-0.53 (0.31)	-
b_2	Δws	1.05* (0.13)	0.96 [†] (0.49)	0.88** (0.06)	1.53* (0.44)	1.54* (0.44)
b_3	$\Delta ws \times I_{ws>ls}$	-2.08 [†] (0.58)	-2.58* (1.05)	-1.04* (0.20)	-1.03* (0.34)	-1.19** (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 (4). Standard errors in parenthesis. Stars denote statistical significance at the [†] $p < 0.10$; * $p < 0.05$; ** $p < 0.01$ level based on robust standard errors clustered by the 5 or 10 year time-period.

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 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.

References

- AKSOY, Y., H. S. BASSO, R. SMITH, AND T. GRASL (2015): “Demographic Structure and Macroeconomic Trends,” *Working Paper*.
- BAIROLIYA, N., R. MILLER, AND A. SAXENA (2017): “The Macroeconomic Impact of Fertility Changes in an Aging Population,” *Working Paper*.
- BLOOM, D. E. AND D. CANNING (2006): “Booms, Busts, and Echoes,” *Finance and Development*, 43, 8–15.
- BLOOM, D. E., D. CANNING, AND G. FINK (2010): “Implications of Population Ageing for Economic Growth,” *Oxford Review of Economic Policy*, 26, 583–612.
- BLOOM, D. E., D. CANNING, G. FINK, AND J. E. FINLAY (2009): “Fertility, Female Labor Force Participation, and the Demographic Dividend,” *Journal of Economic Growth*, 14, 79–101.
- BLOOM, D. E., D. CANNING, AND P. N. MALANEY (1999): “Demographic Change and Economic Growth in Asia,” *Working Paper*.
- BLOOM, D. E., D. CANNING, R. K. MANSFIELD, AND M. MOORE (2007): “Demographic Change, Social Security Systems, and Savings,” *Journal of Monetary Economics*, 54, 92–114.
- BLOOM, D. E., D. CANNING, AND J. SEVILLA (2001): “Economic Growth and the Demographic Transition,” *National Bureau of Economic Research Working Paper*, No. 8685.
- BLOOM, D. E. AND J. E. FINLAY (2009): “Demographic Change and Economic Growth in Asia,” *Asian Economic Policy Review*, 4, 45–64.
- BÖRSCH-SUPAN, A. (2013): “Myths, Scientific Evidence and Economic Policy in an Aging World,” *The Journal of the Economics of Ageing*, 1, 3–15.

- CERVELLATI, M. AND U. SUNDE (2011): “Life Expectancy and Economic Growth: the Role of the Demographic Transition,” *Journal of Economic Growth*, 16, 99–133.
- CERVELLATI, M., U. SUNDE, AND K. F. ZIMMERMANN (2017): “Demographic Dynamics and Long-run Development: Insights for the Secular Stagnation Debate,” *Journal of Population Economics*, 30, 401–432.
- DOEPKE, M. AND M. TERTILT (2016): “Families in Macroeconomics,” *Handbook of Macroeconomics*, 2, 1789–1891.
- GREENWOOD, J., N. GUNER, AND G. VANDENBROUCKE (2017): “Family economics writ large,” *Journal of Economic Literature*, 55, 1346–1434.
- KARABARBOUNIS, L. AND B. NEIMAN (2013): “The Global Decline of the Labor Share,” *The Quarterly Journal of Economics*, 129, 61–103.
- KELLEY, A. C. AND R. M. SCHMIDT (1995): “Aggregate Population and Economic Growth Correlations: the Role of the Components of Demographic Change,” *Demography*, 32, 543–555.
- KUHN, M. AND K. PRETTNER (2015): “Population Age Structure and Consumption Growth: Evidence from National Transfer Accounts,” *Journal of Population Economics*, 1–19.
- LEE, R. (2003): “The Demographic Transition: Three Centuries of Fundamental Change,” *The Journal of Economic Perspectives*, 17, 167–190.
- LEE, R., S.-H. LEE, AND A. MASON (2006): “Charting the Economic Life Cycle,” *National Bureau of Economic Research Working Paper*, No. 12379.
- LEE, R. AND A. MASON (2006): “What is the Demographic Dividend,” *GENUS*, 62, 11–35.

- (2010): “Fertility, Human Capital, and Economic Growth Over the Demographic Transition,” *European Journal of Population/Revue européenne de Démographie*, 26, 159–182.
- LIAO, P.-J. (2011): “Does Demographic Change Matter for Growth?” *European Economic Review*, 55, 659–677.
- MASON, A. AND R. LEE (2006): “Reform and Support Systems for the Elderly in Developing Countries: Capturing the Second Demographic Dividend,” *Genus*, 11–35.
- SAMUELSON, P. A. (1975): “The Optimum Growth Rate for Population,” *International Economic Review*, 531–538.
- SÁNCHEZ-ROMERO, M. (2013): “The Role of Demography on Per Capita Output Growth and Saving Rates,” *Journal of Population Economics*, 26, 1347–1377.