Macroeconomic Dynamics (2025), **29**, e127, pp. 1–24
doi:10.1017/S1365100525100394

ARTICLE

Estimating the growth effect of the demographic dividend

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Abstract

The "demographic dividend" refers to the boost to GDP per capita growth countries experience during the part of the demographic transition when age dependency ratios plummet. The size and the source of the dividend are debated in the literature. Using newly constructed age-specific population data by country from the beginning of the demographic transition to the present day, this paper estimates the contribution of changing age structure to GDP per capita growth during the demographic transition. A quantitative overlapping-generations model is used to produce country-specific estimates of the dividend and to disentangle its drivers. Model simulations for 101 countries suggest a global average boost of 0.40 percentage points per annum to GDP per capita growth during the dividend period. Changing age structure explains 9.5% of total growth during the period of the demographic dividend on average. Countries with more rapid and more extreme changes in age structure experience larger dividends.

Keywords: demographic dividend; demographic transition; age structure; human capital

JEL classifications: J11; O11; O40; E20

1. Introduction

All countries have undergone or are currently undergoing a demographic transition (Delventhal et al. 2021). The theory of the demographic transition was first established by authors such as Thompson (1929), Landry (1934), Notestein et al. (1944), and it is closely related to the idea of the epidemiological transition first proposed by Omran (1971). During this time period, countries gradually transition from high to low levels of mortality and fertility. However, mortality and fertility do not adjust simultaneously. There is generally a lag with mortality starting its decline before fertility. Thus countries go through a period of high fertility and low mortality during which population grows rapidly. But once fertility does decline, the size of new cohorts becomes relatively small and the share of the working-age population increases. The benefits stemming from this relatively large working-age population have been referred to as the "demographic dividend" (Bloom et al. 2003). In this paper, the term demographic dividend will refer specifically to the positive effect a large working-age population has on GDP per capita growth rates during this time period.

Two key questions of interest about the demographic dividend have been its size and its drivers. Regarding its size, the dividend is usually measured by its contribution to annual GDP per capita growth. Existing estimates are primarily based on purely empirical methods such as growth accounting and cross-country regressions (Bloom and Williamson, 1998; Kelley and Schmidt, 2005; Lee and Mason, 2006; Eastwood and Lipton, 2011). There is also some disagreement on the size of the dividend with estimates ranging from 0.3% to 3.5% (Eastwood and Lipton, 2012). Regarding the drivers, the traditional view holds that it is the changing age structure during the fertility decline that primarily drives higher growth rates. As fertility declines, there is a temporary increase in a country's working-age population relative to dependents, which lifts GDP per capita. However, recently a new view has been emerging, which argues that it is instead increases in educational attainment that produce most of the demographic dividend. The argument is that improvements in human capital are happening simultaneously with the fertility decline, and that earlier studies did not properly account for changes in educational attainment thereby overestimating the contribution of age structure to growth during the demographic transition (Crespo Cuaresma et al. 2014; Rentería et al. 2016; Baerlocher et al. 2019; Lutz et al. 2019). These authors argue that once human capital is properly accounted for, age structure only has a quantitatively insignificant "accounting" effect on GDP per capita.[1] But there is still disagreement in the literature about how significant a role age structure plays in the demographic dividend (Kotschy et al. 2020).

This paper investigates the size and the source of the demographic dividend using a quantitative overlapping-generations (OLG) model. The model is calibrated separately to 101 countries, and provides country-specific estimates of the dividend as well as of the relative importance of age structure and human capital in GDP per capita growth during the demographic transition.

The model is a fairly standard general equilibrium OLG model in which households are split into 21 generations of 5-year age groups. The age structure of the population is exogenous. Households make decisions about how much to work, consume and save in each period, and they pay for the human capital of their children. Human capital, in turn, drives technological progress. The model is calibrated separately to each country, and is able to match the growth take-off observed during the demographic transition. The use of an OLG model to study the demographic dividend is motivated by the fact that this model takes into account households' response to a changing age structure in terms of their consumption, saving, and labour supply decisions. These decisions can affect the amount of capital and labour available for production, and could exert additional forces on economic growth on top of the direct forces exerted by the changing age structure. An OLG model allows for properly accounting for these phenomena, which is important for obtaining accurate estimates of the demographic dividend.

One could think of the channels behind GDP per capita growth using the unified growth perspective (Galor and Weil, 2000) as follows. Technological progress increases returns to education and investment in human capital. This will have a direct effect on growth. But it will also spin off two indirect effects through a reduction in fertility following the quantity-quality trade-off. First, lower fertility will ultimately change the population's age structure and deliver the demographic dividend. Second, lower fertility will also induce households to invest more in their children's human capital. To isolate the demographic dividend, the human capital channels are shut down in the calibrated model.

The paper has three key findings. First, the size of the demographic dividend varies over time and space with a global average effect of adding 0.40 percentage points to annual GDP per capita growth rates during the dividend period. The size of the dividend varies over time because the fraction of the working-age population changes gradually over the course of the transition, and it is to be expected that the dividend will be stronger when the age dependency ratios are smaller. The dividend also varies between countries due to different country characteristics (captured by model parameters such as capital share, time preferences, etc.), and due to the demographic transition being different in each country, e.g. in terms of speed. The dividend is strongest in current upper-middle income countries and weakest in current low-income countries—in line with Reher (2011). On average, countries experience up to 7.9% higher GDP per capita during the period of the demographic dividend compared to a counterfactual with no changes in age structure.

Second, age structure is found to be an important driver of GDP per capita growth during the period of the demographic dividend. On average, changing age structure contributes about 9.5% of total GDP per capita growth during the period of the demographic dividend with the balance made up by the various human capital channels. As such, this paper finds that human capital is indeed the key driver of growth during the dividend period, but that age structure still matters a great deal.

Third, given that the model simulations produce country-specific estimates of the demographic dividend, it is possible to see what factors the dividend correlates with. A correlational analysis finds that countries with shorter transitions experience an elevated demographic dividend. This finding is consistent with Hahn and Park (2010) who find in cross-country regressions that countries with shorter transitions experience faster GDP per capita growth during the transition. It is also observed that countries whose old-age dependency ratio (OADR) is more elevated at the end of the transition experience a more elevated demographic dividend. Overall, countries with more "extreme" movements in age structure (whether proxied by speed or degree of eventual ageing) have higher dividends during the transition.

A few additional results are also established. To start, it is verified that the paper's key results are largely insensitive to intergenerational redistribution. That is, introducing a basic pension system in the model does meaningfully alter the estimates of the dividend. Further, a sensitivity analysis reveals that the results do not depend significantly on the specific parameter values chosen for each country. Finally, the effect of age structure on GDP per capita growth is also examined for a few Western countries during the baby boom period following World War 2. It is found that the baby boom had largely similar quantitative effects on growth as the "classic" demographic dividend.

In addition to contributing to the primarily empirical literature on the size and the source of the demographic dividend described above, this paper is related to a number of studies that have used economic-demographic models to consider the macroeconomic effects of demographic changes (Denton and Spencer, 1973; Simon, 1976; Liao, 2011; Ashraf et al. 2013; Mason et al. 2016; Abío et al. 2017; Bairoliya and Miller, 2021). Compared to these papers, the novelty of the present manuscript is threefold. First, other studies have not considered a rational expectations, general equilibrium framework with endogenous labour supply. As a result, they do not explicitly model forward-looking household decision-making in a general equilibrium set-up where households labour supply decisions can endogenously change during the demographic transition. Second, the majority of past studies either did not carry out an empirically grounded calibration, or they focused on specific countries. This paper calibrates the model parameters to a large number of countries. Finally, as seen above, the literature has found somewhat contradictory results about the relative importance of education and age structure. To the best of my knowledge, this paper is the first one to explore this issue in a quantitative model as opposed to a purely empirical set-up.

A limitation of this paper is that it treats population numbers as exogenous. One could argue that in the absence of increases in human capital, there would not have been a demographic transition and changes in age structure. It lies beyond the scope of this paper to consider this issue. The paper takes population numbers from the data as a given, and estimates to what extent the subsequent changes in dependency ratios affected GDP per capita growth once human capital is separately accounted for. The key contribution thus lies in separating out the effect of age structure and human capital on economic growth, rather than in contributing to the debate on the ultimate origins of population age structure changes.

The rest of the paper is organised as follows. Section 2 introduces the model, Section 3 discusses how the model is taken to the data, Section 4 presents the results from the model simulations, and Section 5 concludes.

2. Model

This section presents the model of the paper, which is a general equilibrium OLG model featuring rational expectations. It has 21 generations, each corresponding to a five-year age group covering ages 0–100. The behaviour of households is described first, followed by firm decision-making, the definition of general equilibrium, the implementation of intergenerational redistribution, and finally the method for solving the model numerically.

https://doi.org/10.1017/S1365100525100394 Published online by Cambridge University Press

2.1 Households

Households live for 21 periods, each period corresponding to a five-year age group spanning ages 0–100. In particular, following the UN World Population Projections (United Nations, 2019), households are grouped into age categories of 0–4, 5–9, . . . , 95–99, and 100+.

There are three stages of life: childhood, adulthood, and retirement, which is standard in OLG models with human capital accumulation (see e.g. de la Croix and Michel (2002)). The reason for this split is that what matters from an economic perspective about the stages of life is the economic function an individual fills in any given stage of life. In childhood, people are assumed not to work, rely on their parents for consumption, and accumulate human capital. In adulthood, people work and use their income to consume and save. In retirement, people no longer work, but support themselves financially from previously accumulated savings and potential pension benefits. The concept of life stages has long been present in the demography literature—in particular, studies exploring life-cycle patterns in mortality have identified roughly the same three life stages that are used in this paper (Gompertz, 1825; Heligman and Pollard, 1980; Redmund et al. 2018).

In the model, the length of life stages is allowed to vary by country depending on average years of schooling data. For instance, for high-income countries, there are four periods of childhood (ages 0–19), nine periods of adulthood (ages 20–64), and eight periods of retirement (ages 65–100+). In childhood, households acquire human capital. In adulthood, they work, consume, save, and pay for their children's human capital. In retirement, they live off their savings. A household born in period j solves the following utility maximisation problem at the beginning of adulthood,

$$\max_{\{c_{t,j}\}_{t=0}^{T-1},\{a_{t+1,j}\}_{t=0}^{T-1},\ell_j} \sum_{t=0}^{T-1} \beta^t \frac{c_{t,j}^{1-\theta}}{1-\theta} - \phi \frac{\ell_j^{1+1/\psi}}{1+1/\psi} \text{ subject to} \tag{1}$$

$$\begin{aligned} c_{t,j} + a_{t+1,j} &\leq w_t \ell_j h_j \left(1 - \kappa \frac{N_{t,j+4}}{N_{t,j}}\right) \\ &\quad + (1+r_t) a_{t,j} \text{ for } t \in [0, W-1] \\ c_{t,j} + a_{t+1,j} &\leq w_t \ell_j h_j + (1+r_t) a_{t,j} \text{ for } t \in [W, R-1] \\ c_t + a_{t+1} &\leq (1+r_t) a_t \text{ for } t \in [R, T-1] \\ a_0 &\text{ given,} \end{aligned}$$

where $t = 0$ is the first period of adulthood, T is the number of periods in life excluding youth, W is the period in which working life begins, R is the period (excluding youth) in which retirement starts, $c_{t,j}$ is consumption at time t for the household born at time j, $a_{t,j}$ is asset holdings, $\ell_j \in (0, 1]$ is labour supply, $\phi > 0$ is the disutility of labour, $\psi > 0$ is the Frisch elasticity, w_t is the wage rate, h_j is human capital, r_t is the return on assets, $\beta \in (0, 1)$ is the discount factor, $\theta > 0$ is the coefficient of relative risk aversion, $\kappa > 0$ is a parameter governing the per-period per-child cost of human capital, and $N_{t,j}$ is the size of the cohort born in time period j. The term $\kappa \frac{N_{t,j+4}}{N_{t,j}}$ represents the fraction of labour income that is spent on children's human capital.

Each household gives birth to children in the first period of adult life (age 20–24). So children are four cohorts younger than parents, i.e. the generation born in j are the parents of the generation born in $j + 4$. E.g. the children of the 20–24-year-old cohort are the members of the 0–4-year-old cohort, the children of the 25–29-year-old cohort are the members of the 5–9-year-old cohort, etc. Children are divided equally between households. So a household born in period j has $\frac{N_{t,j+4}}{N_{t,j}}$ surviving children. The cost of human capital is equally spread out over the four periods of childhood.

An important modelling assumption in the household problem is the exogeneity of cohort sizes ($N_{t,j}$). This approach is also taken by e.g. Ashraf et al. (2013); Mason et al. (2016). In contrast, other studies, such as Galor and Weil (2000), assume population size is an endogenous outcome of household optimisation. The exogenous approach taken in this paper essentially assumes that the exogenous population data is an outcome of household optimisation. Instead of explicitly modelling such an optimisation, it takes a shortcut by feeding actual population data into the model. There are three key reasons why the exogenous approach is particularly useful here. First, the endogenous approach would require calibrating fertility parameters to match exogenous population data, which would be computationally intensive due to the fact that a large number of countries are simulated for long periods with 21 age cohorts to keep track of in each period. Second, it would also be difficult to match such a large number of data points (21 cohort sizes in each time period over the course of several decades or centuries) in a parsimonious model. Third, the endogenous approach could only reproduce a smooth path for population as it would not be able to match country-specific idiosyncratic fluctuations brought on by e.g. wars or regime changes. This is especially problematic in the present setting where cross-country differences in the size of the demographic dividend are of primary interest.

2.1.1 Human capital

Each cohort acquires human capital (h_j), which is uniform within cohorts but can vary across cohorts. Investment in human capital follows the equation

$$\ln h_{j+4} = \sigma \left(1 - \frac{N_{t,j+4}}{N_{t,j}}\right) + \chi \ln A_t,$$

where $\sigma \geq 0$ is a measure of the quantity-quality trade-off, $\frac{N_{t,j+4}}{N_{t,j}}$ is the number of children per household, $\chi \geq 0$ measures the sensitivity of human capital investment to the level of technology, and $A_t > 0$ is total factor productivity (TFP). It is apparent that human capital is decreasing in the number of children per household, which represents a trade-off between child quantity and quality. In this formulation, one additional child decreases human capital by 100σ percent. The presence of a quantity-quality trade-off as well as the positive influence of technology on human capital investment are both present in Unified Growth Theory (Galor and Weil, 2000).

The behaviour of human capital in the model can be thought of as exogenous because it is not the outcome of household-level optimisation. This is certainly a limitation of the model. One reason for this modelling decision is to reduce computational complexity, especially since the model is simulated for a large number of countries. Nevertheless, the above specification for the determination of human capital does take into account two key drivers of human capital decisions: the role of the quantity-quality trade-off and technology. Furthermore, to the extent that cohort sizes drive wages, the presence of $N_{t,j+4}/N_{t,j}$ in the human capital equation also accounts for the effect of future wages on human capital decisions. Finally, the presence of A_t also captures the positive externality of human capital: that is, that current investments in human capital depend on the level of aggregate human capital, which is a crucial ingredient in growth models with human capital (de la Croix and Michel, 2002).

2.2 Firms

There are two factors of production: capital (K_t) and effective labour (L_t). Effective labour is the product of the working-age population and cohort-specific human capital stock,

$$L_t = \sum_{j \in \mathcal{A}_t} h_j N_{t,j},$$

where $\mathcal{A}_t = \{t-12, t-11, \ldots, t-4\}$ is the set of adult cohorts (ages 20–64) at time t.

https://doi.org/10.1017/S1365100525100394 Published online by Cambridge University Press

Firms use a Cobb-Douglas production function to combine capital and effective labour into a final consumption good. The profit maximisation problem is thus

$$\max_{L_t,K_t} A_t K_t^{\alpha} L_t^{1-\alpha} - (r_t + \delta)K_t - w_t L_t, \tag{2}$$

where A_t is TFP in period t, K_t is physical capital, L_t is effective labour, $\alpha \in (0, 1)$ is the capital share, and $\delta \in (0, 1)$ is the depreciation rate of capital.

TFP is a function of aggregate human capital,

$$A_t = \left(\sum_{j \in \mathcal{A}_t} h_{j,t} N_{j,t} \right)^{\epsilon},$$

where $\epsilon > 0$ measures the sensitivity of TFP to human capital. In this formulation, TFP is driven by both population size (Kremer, 1993) and population composition (Galor and Weil, 2000). Admittedly, this specification for TFP abstracts away from explicitly modelling the endogenous formation of TFP more carefully by incorporating factors such as R&D expenditures as in e.g. Aghion and Howitt (1992).

2.3 Equilibrium

General equilibrium is defined as a set of variables $\{c_t, a_{t+1}, w_t, r_t, K_t, L_t\}_{t=0}^{F}$ for which

- households maximise utility according to (1),
- firms maximise profits according to (2),
- and w_t and r_t are determined by labour and capital market clearing.

Market clearing in the labour market means effective labour demand and supply are equal,

$$L_t = \sum_{j \in \mathcal{A}_t} h_j N_{t,j}.$$

Similarly, capital market clearing means

$$K_t = \sum_{j=t}^{t-20} a_{t,j} N_{t,j},$$

where $a_{t,j}$ is the asset holdings of the cohort born at time j. Capital supply is thus the sum of assets across all living cohorts.

2.4 Intergenerational redistribution

The paper also considers whether intergenerational redistribution, in the form of a pension system, has any effect on the size of the demographic dividend. This entails two changes to the baseline model presented above. First, there has to be source of tax revenue for the government. Two options will be considered here: a labour tax and a capital tax. Second, retired households have an additional pension income which amounts to $\gamma w_t h_j$, where $\gamma \in [0, 1]$ is the replacement rate, i.e. the percent of the prevailing wage rate paid to pensioners.

If the pension system is financed through labour taxation, then wage income becomes $(1 - \tau) w_t h_j$, where $\tau \in [0, 1)$ is the labour tax rate. If the pension system is financed through capital taxation, then the return on capital becomes $r_t(1 - \tau_r)$, where $\tau_r \in [0, 1)$ is the capital tax rate.

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The pension system's budget balances in every period t. If there is labour taxation, this means

$$\sum_{j\in\mathcal{A}_t} \tau w_t h_j N_{t,j} = \sum_{j\in\mathcal{R}_t} \gamma w_t h_j N_{t,j},$$

where $\mathcal{R}_t = \{t-20, t-19, \ldots, t-13\}$ is the set of retired cohorts (ages 65+) at time t. If there is capital taxation, this means

$$\tau_r r_t \sum_{j=t}^{t-20} a_{t,j} N_{t,j} = \sum_{j\in\mathcal{R}_t} \gamma w_t h_j N_{t,j}.$$

The balanced budget equation implies that pension tax revenues are equal to pension payments in any given period. The tax rate is set to whatever is necessary to reach an exogenous replacement rate of γ, i.e.

$$\tau = \gamma \frac{\sum_{j\in\mathcal{R}_t} h_j N_{t,j}}{\sum_{j\in\mathcal{A}_t} h_j N_{t,j}}$$

$$\tau_r = \gamma \frac{w_t \sum_{j\in\mathcal{R}_t} h_j N_{t,j}}{r_t \sum_{j=t}^{t-20} a_{t,j} N_{t,j}},$$

for labour and capital taxation, respectively. Naturally, this implies that the extended model collapses to the baseline model if $\gamma = 0$.

2.5 Model solution

The model is solved quantitatively, separately for a large number of countries. The time path of population ($N_{t,j}$) is exogenous. Population starts in an initial steady state, then it goes through a demographic transition, and eventually it reaches a final steady state. The initial and final steady states are characterised by a constant population age structure. The demographic transition itself is then modelled as the transition path between the two steady states. The solution algorithm follows the one developed by Auerbach and Kotlikoff (1987). It is described in detail in Online Appendix A.

The primary variable of interest is GDP per capita. This is defined as GDP divided by total population, i.e. $Y_t/(\sum_j N_{t,j})$. Whenever the term "(economic) growth" is used in the manuscript, it refers to growth in this variable.

3. Data and methodology

This section describes how the model is taken to the data. First, it is explained how population data ($N_{t,j}$) is constructed for each country. Second, parameter sources and the model's calibration are discussed. Finally, it is described how the demographic dividend's effect is isolated within the model.

3.1 Population data

In order to simulate the demographic transition, the model needs age-specific population size data in five-year age groups from the beginning to the end of the transition. To the best of my knowledge, such extensive data is not available. The closest is the United Nations World Population Prospects (UN WPP) (United Nations, 2019), which has this data from 1950 onward. Data for the pre-1950 period is thus constructed from other data sources according to the procedure described below.

The time period of the analysis varies by country. For each country, the first year considered is when the demographic transition started in that country according to Delventhal et al. (2021). The earliest start date is 1700 for the United States. The latest start date is 1945 for Equatorial Guinea, Nepal, and South Korea. The analysis then uses demographic data until 2100. Actual data is used until 2020, UN WPP projections are used for the remaining years up to 2100.

The UN WPP rely on demographic data from national statistical agencies where available. When no such data is available and for forecasts, the UN WPP uses model-based estimates of demographic variables which come with their own assumptions. For a more detailed discussion of the methods used in the construction of the UN WPP, see e.g. World Health Organization (2018). It is important to mention that the UN WPP projections use specific models to forecast fertility and mortality rates. There is some disagreement in the demography literature about the appropriateness of the models used by the UN WPP (Atance et al. 2024). For instance, Li et al. (2013) point out that changing patterns in mortality decline would need to be incorporated into long-term population projections to ensure accuracy. Overall, the UN WPP represent just one of many potential future demographic scenarios.

3.2 Data for the pre-1950 time period

To characterise the timing and pace of the demographic transition by country, estimates for the beginning and end of the crude death rate (CDR) and crude birth rate (CBR) transitions are used from Delventhal et al. (2021). For countries where both the CDR and CBR transition started after 1950, the UN data is used. For countries where either transition started earlier, pre-1950 population data is constructed using the following steps.

First, given the beginning and end dates of the CDR and CBR transitions, an initial and final population age structure needs to be assumed. The initial (pre-transition) age structure is assumed to be the same for all countries as that for the Central African Republic in 1960 from UN data. The Central African Republic started its demographic transition in 1961 (Delventhal et al. 2021), so this age structure is seen as a rough approximation for what populations look like just before the transition. The final population age structure is the one observed in 1950 from UN data.[2] From 1950 onward, the paper uses actual population age structure data from the UN.

Second, given the initial and final age structures, an initial and final CBR can be calculated. It is assumed that the CBR transitions between these two in a linear fashion over the number of years implied by the CBR transition start and end dates. Further, an initial and final set of age-specific survival rates (ASSR) can be constructed. It is assumed that each age cohort's ASSR converges from the initial to the final in a linear fashion over the number of years implied by the CDR transition start and end dates. At this juncture, the CBRs and the ASSRs have been estimated for every year from the beginning of the demographic transition to 1950. Using these numbers, population age structure can be inferred for the entire transition path. This procedure implies a demographic convergence among countries, for which there is indeed support in the data (Wilson, 2001, 2011).

Finally, the population totals from the constructed population path are adjusted so that they line up with historical population totals from the Maddison project (Bolt and van Zanden, 2020) for up to 1800, and from GapMinder (2019) for 1800–1950. Each age group is scaled equally to ensure accurate population totals.

Overall, the model simulations are carried out for 101 countries listed in Table D1 in the Online Appendix. There are two main reasons why a country may be missing from the sample. First, countries for which Delventhal et al. (2021) do not provide a start date for the fertility or mortality decline cannot be included as the dates of the demographic transition are unknown. There are 47 such countries including e.g. Australia, Canada, China, Israel, Poland, or Switzerland. Second, for some countries the model either cannot be calibrated successfully to the data, or the transition path cannot be solved successfully. Large-scale computational models may require the fine-tuning

https://doi.org/10.1017/S1365100525100394 Published online by Cambridge University Press

of initial conditions and tolerance parameters to get the model to converge to a solution. Given the large number of countries considered, it is not feasible to troubleshoot these issues on a case-by-case basis which is the second reason why certain countries are not included in the paper.

Illustration of population data

To illustrate the constructed population data, Figures C1–C3 in the Online Appendix show how population and age dependency ratios evolve over the course of the demographic transition for a selection of countries including two high-income countries (United Kingdom and Singapore), one upper-middle income country (Indonesia), one lower-middle income country (India), and one low-income country (Ethiopia). For the UK in Figure C1, the transition starts in 1794 with decreasing mortality. This leads to an increasing population and a slightly increasing young-age dependency ratio (YADR).[3] The fertility decline starts in 1885, which brings with it a rapid drop in the YADR. This continues until the baby boom, which leads to a temporary bump in YADR, and the OADR also starts increasing around this time. The data from 1950 onward are directly taken from the UN, and from 2020 onward they are based on UN population projections.

For Singapore in Figure, the picture of a classic demographic transition emerges in Figure C2. The mortality transition starts in 1910 leading to increasing YADR. The mortality transition ends and the fertility transition begin around 1960, which leads to a sharp decline in YADR. Population ageing leads to increase OADR particularly from the 2000s onward. As for the UK, the data for the post-1950 period are taken directly from the UN.

For Indonesia, India, and Ethiopia, the patterns shown in Figure C3 are very similar to that of Singapore: increasing age dependency ratios followed by a transitory decline and another increase driven by population ageing. It is apparent from the age dependency ratio graphs that the transition occurs earlier in the middle-income countries of Indonesia and India than in the low-income country of Ethiopia.

While the pre-1950 data are approximations, these figures are meant to illustrate that these approximations do a reasonable job at capturing the basic stylised facts of the demographic transition as well as its different pace in different countries.

3.3 Parameter sources and calibration

There are three types of parameters: country-specific parameters whose values are taken from the literature, global parameters, and country-specific parameters which are calibrated.

Country-specific parameters from the literature

Parameters for which country-specific estimates are used from the literature are shown in Table D2 in the Online Appendix, and they include

- the coefficient of relative risk aversion (θ) taken from Gandelman and Hernández-Murillo (2015),
- capital's share in production (α) calculated as the 1950–2019 mean from the Penn World Table (Feenstra et al. 2015),
- capital's depreciation rate (δ) calculated as the 1950–2019 mean from the Penn World Table (Feenstra et al. 2015),
- the discount factor (β) calculated from a combination of World Bank data on the risk-free interest rate and long-term orientation (LTO) data from Hofstede (2010),
- and the timing of the life-cycle (T, W, R) is set using guidance from average years of schooling data from Barro and Lee (2013).

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The calculation of the discount factor (β) follows the following procedure. Begin by obtaining a GDP-weighted global average risk-free interest rate from the World Bank. Then for each country take this rate and adjust it up or down depending on the LTO of the country. The LTO concept comes from cross-cultural psychology. It was first constructed by Hofstede (1980) from survey evidence, and is meant to measure to how much people in a given country value the future. High LTO countries focus more on perseverance, thrift, savings, and adaptability. In economics, LTO has been used to capture time preferences by e.g. Galor and Özak (2016). LTO is measured as an index spanning 0–100. The LTO adjustment factor for country i is calculated as $LTOAdj_i = (LTO_i - 50)/100$. The country-specific discount rate is then $r_i = r_{global}(1 - LTOAdj_i)$. This means a country with an LTO of 50 will not be adjusted, whereas countries at either end (LTO of 0 or 100) will be adjusted by $\pm$50%. Given a global average risk-free rate of 3.02%, this procedure bounds the annual discount rate between 1.51% and 4.53%, and the five-year discount factor between 0.8013 and 0.9278. The reason this procedure is used is because country-specific risk-free rate data is unavailable for a large number of countries.

The timing of the life-cycle (T, W, R) is set as follows. Working life starts after the age bracket in which the average years of schooling would be completed. For instance, if average years of schooling is 10, schooling would be completed at age 16 (it is assumed that schooling starts at 6), which means schooling would conclude in the 15–19 age bracket. In this case, working life or adulthood would start in the 20–24 age bracket, which corresponds to $W = 5$. Working life is assumed to be 9 periods (45 years), which means $R = 10$. In the above example, this would correspond to the 65–69 age bracket. Finally, T is set to ensure that the last period of life falls into the 100+ age bracket. For the above example, this happens at $T = 17$.

Global parameters

There are four global parameters in the model: the pension replacement rate (γ), the quantity-quality trade-off parameter (σ) that measures the sensitivity of human capital to fertility, the Frisch elasticity (ψ), and the disutility of labour (ϕ).

The pension system's replacement rate (γ) is set to 0 in the baseline simulations shutting down intergenerational redistribution. Getting accurate numbers on γ is difficult due to data availability issues and the fact that pension systems vary a lot across time and space. To get a rough idea of the impact of intergenerational redistribution on the demographic dividend, a version of the model with $\gamma = 0.60$ is simulated. This represents a system where pension income is 60% of last period wage income, which approximately corresponds to the OECD average replacement rate in the past decade (OECD, 2022). In a more refined formulation, the model is also simulated with country-specific replacement rates. However, these are only available for 23 countries in the sample, and only for the past decade.

The quantity-quality trade-off parameter (σ) measures by what percent one additional child decreases human capital. There are a number of papers estimating the empirical size of this trade-off. Some authors find no significant trade-off suggesting that $\sigma = 0$ (Black et al. 2005; Angrist et al. 2010). Others are able to identify a usually rather moderate trade-off: Cáceres-Delpiano (2006) finds more children reduces the chance of private school attendance, Li et al. (2008) find one additional child leads to a loss of about 0.16 years of schooling, Liu (2014) finds one additional child leads to a 0.5 standard deviation lower height, and most recently Bhalotra and Clarke (2020) find that one additional child leads to a loss of about 0.30–0.36 years of schooling in the US and 0.12–0.15 years in developing countries.

The most recent and robust estimate from Bhalotra and Clarke (2020) provides the baseline value for σ in this paper. Assuming 12–16 years of schooling in the US and 4–8 years in developing countries, their estimates translate into a σ of 0.01875–0.0300 in the US and 0.0150–0.0375 in developing countries. The estimate from Li et al. (2008) is in accordance with these numbers as well. As a result, the baseline σ in the paper takes the value of 0.03. Estimates from other papers are not directly convertible into percent schooling reductions. Finally, note that if one relies instead on the $\sigma = 0$ estimates from Black et al. (2005) and Angrist et al. (2010), then the quantity-quality trade-off is shut down as human capital does not respond to fertility. A sensitivity analysis of the paper's main results is conducted with $\sigma = 0$ as well.

As for the labour parameters, these are global because widely available country-specific estimates do not exist for them. However, the sensitivity analysis in Section 4.5 confirms that the quantitative size of the main results is not sensitive to their choices. The size of the Frisch elasticity is taken as the central estimate from Whalen and Reichling (2017), which is 0.40. In the sensitivity analysis, the minimum and maximum of their range (0.27 and 0.53) are used as alternatives. For the disutility of labour, a value of 13 is taken from Jacobs (2009), and in the sensitivity analysis this value is halved and doubled to cover a range of 6.5–26, which is similar to the range considered by e.g. Fanti and Spataro (2006).

Calibrated parameters

The parameters measuring the cost of human capital (κ), the sensitivity of technology to aggregate human capital (ϵ), and the sensitivity of human capital to technology (χ) are calibrated by matching three data points. The targeted data points for calibration are education spending as a percent of GDP, the change in GDP per capita between the start of the demographic transition and 2100 (y_T/y_0), and the change in human capital between the start of the demographic transition and 2100 (h_T/h_0).

GDP per capita and human capital for 2100 are used because 2100 is the final steady state of the model and it is much less computationally intensive to match a target in the steady state rather than during transition. GDP per capita and human capital for 2100 are estimated by assuming that the frontier country (USA) is growing at the rate of 1%. Other countries are grouped into five buckets depending on how far they are from the frontier. For each bucket, historical average growth rates are used. As countries farther from the frontier tend to have higher growth rates, there is catch-up growth and the advancement of countries to buckets closer to the frontier. Human capital is measured by the human capital index from Lee and Lee (2016) which is available from 1820 onward.

The calibration procedure itself is as follows. Let us denote the vector of the three targeted data points as m, and the model's output for the same variables as $f(\kappa, \epsilon, \chi)$. The parameters are then obtained by minimising the distance between the data and the model's output by solving

$$\{\hat{\kappa}, \hat{\epsilon}, \hat{\chi}\} = \arg\min_{\{\kappa,\epsilon,\chi\}} (m - f(\kappa, \epsilon, \chi))' W (m - f(\kappa, \epsilon, \chi)),$$

where W is a 3×3 weighting matrix whose diagonal elements are $1/m_i$ in row i. The calibration procedure does a good job matching the data for the vast majority of countries as shown in Table D2. In particular, the growth take-off associated with the demographic transition is reprodced well by the model as shown by the black lines in Figure C6 for the UK and Singapore.

Model fit

The key variable the model simulates is GDP per capita. It is, therefore, interesting to see how well the model is able to match the data for this variable. Figure C4 shows how well model-generated GDP per capita stacks up against actual GDP per capita for the set of countries where sufficient GDP per capita data is available. The figure shows the correlation coefficient between the actual and model-generated GDP per capita time series for each country separately. By and large, the correlations are strong (over 0.9).

It must be noted though that the fit is not so perfect for all countries. In particular, it is nearly impossible for the model to match big shocks, such as large-scale institutional changes or wars, that completely alter a country's GDP per capita trajectory for decades. This might explain the lower correlation between data and model for countries such as Syria (e.g. the Syrian civil war), Venezuela (e.g. the regime change from the Fourth Republic to the Bolivarian era) or Japan (e.g. the crash in asset prices in the 1990s and the ensuing Lost Decades).

3.4 Estimating the growth effect of the dividend

To estimate the growth effect of the demographic dividend, the paper proceeds in two steps. First, the time periods associated with the dividend are identified by an algorithm. Second, growth due to the dividend during those time periods is isolated. These two steps are discussed in what follows. Afterwards, the limitations of these estimates are explained.

Identifying the dividend periods

As is apparent from Figures C1–C3, the age dependency ratio tends to worsen at the beginning of the demographic transition due to an increasing YADR. At this stage, the age composition channel is exerting a negative effect on economic growth by increasing the share of dependents. This phenomenon is very prevalent for Singapore in Figure C2. In this paper, this stage of the demographic transition is referred to as the "negative dividend," Bloom and Williamson (1998) call it the "demographic burden." As the demographic transition advances, countries enter a phase of decreasing age dependency ratios. This period is characterised by the increase in the share of the working-age population and thus a positive effect on economic growth. This is the classic demographic dividend, which in this paper is also called the "positive dividend" to distinguish it from the negative dividend.

The demographic transition thus, broadly speaking, gives rise to a period with negative growth effects ("negative dividend") followed by a period with positive growth effects ("positive dividend"). The timing of each period is identified for each country by a simple algorithm that looks for time intervals of continuous negative or positive growth in the fraction of the working-age population. For a detailed description of the algorithm, see Online Appendix B. The results of the algorithm are illustrated for the UK and Singapore in Figure C5. As is visible, the algorithm does a good job of picking out the sustained drop in worker share at the beginning of the transition (red, negative dividend) as well as the sustained increase in worker share in the subsequent stage (blue, positive dividend).

It is also apparent from Figure C5 that the demographic transition is not always a smooth process. For instance, in the case of the UK, the blue positive dividend period of increasing working-age share is interrupted by World War 2. After the interruption, there is a second instance of increasing working-age share highlighted in green. This is the post-war baby boom. In cases like this, the algorithm only identifies the first instance of sustained working-age share increases. In the UK's case this includes the period prior to World War 2 (blue) but not the baby boom (green), as is visible in Figure C5. Section 4.6 separately analyses the growth effects of the baby boom for countries that experienced it.[4] The period of the baby boom corresponds to the second sustained period of growth in workers' share in select countries, e.g. the time period highlighted in green for the UK in Figure C5. This is identified using the same algorithm that is used for identifying the dividend.

Calculating dividend-driven growth

To calculate the fraction of growth that was contributed by changing age structure during the positive and negative dividend periods, other drivers of growth are shut down. In particular, the human capital channel is extinguished by setting $\sigma = \epsilon = \chi = 0$. Setting $\sigma = 0$ ensures that human capital does not respond to fertility. This is necessary, because if this channel is operational, then more favourable dependency ratios also lead to increasing human capital through

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the quantity-quality trade-off. It would then be difficult to disentangle whether growth is being driven by changes in age structure or the associated improvements in human capital. Setting $\chi = 0$ means that human capital does not respond to technological change. This is necessary to ensure that increased investments in human capital do not happen in response to technological progress. This keeps human capital from driving growth by increased investment due to higher returns to education. Finally, setting $\epsilon = 0$ ensures that technological progress does not respond to human capital. This is to ensure that human capital does not indirectly drive growth by increasing TFP. Note that the assumption of $\epsilon = 0$ implies constant TFP as aggregate human capital is no longer allowed to drive TFP growth. One could think of this as a counterfactual in which technological progress is turned off, but the age structure changes associated with technological progress are allowed to take place. The growth generated in this counterfactual is, therefore, the amount of growth contributed purely by changing age structure and not human capital or technological progress. The growth rates from this counterfactual simulation of the model are the growth rates associated with the demographic dividend.

Using this information, GDP per capita can be plotted with and without the inclusion of the growth contributed by changing age structure. The red lines in Figure C6 show GDP per capita without the dividend, while the black ones show GDP per capita with the dividend for the case of the UK and Singapore. At the beginning of the transition, an increasing YADR and a decreasing worker share exert a negative force on economic growth. This is the negative dividend, and it is visible on the left-hand side of Figure C6 as the red line rising above the black one. This phenomenon is essentially imperceptible for the UK as it turns out to have a very small negative dividend (see Table D3), but it is clearly visible for Singapore. Then, as dependency ratios start falling and worker share rises, the positive dividend materialises and is seen in Figure C6 as the black line rising above the red one. For the UK this positive dividend temporarily disappears mid-century, but it is revived during the post-World War 2 baby boom period. Once the positive dividend is over, the two lines converge as population ageing leads to falling worker share again, but studying the impact of population ageing lies beyond the scope of this paper. Section 4 analyses in detail the differences between the baseline and the counterfactual without the dividend.

Limitations of dividend estimates

One shortcoming of the analysis is the inability to fully take into account all drivers of labour supply. Namely, migration flows and changes in female labour force participation (FLFP) may also have affected labour supply and age composition during the demographic transition, so these factors might also affect the size of the estimated demographic dividend.

How could these two factors affect the analysis? Migratory flows are taken into account in the data. That is, the population data that is fed into the model includes net migration volumes. As a result, the effect of migration on age composition is in the data, and it may bias the estimates of the demographic dividend. How it does so depends on the specific timing and composition of the migrant flows. E.g. if there is a lot of working-age immigration during the negative dividend period of increasing dependency ratios, then this would offset the initial rise in dependency ratios. This might make the positive dividend look smaller.

FLFP is not taken into account in the analysis. What this means is that to the extent that the model matches observed rates of output per capita growth, it may misattribute FLFP-driven growth to either age structure or other factors like human capital or technology. However, this may not be a large concern because FLFP seemingly tends to rise during later stages of development than where the demographic dividend occurs. For instance, in the US the positive dividend period of increasing worker share started in the early 1800s and concluded in the mid-1920s, whereas FLFP only started rising in the 1940–1950s (Fogli and Veldkamp, 2011). Some authors have also noted that FLFP follows a U-shape during the process of development: first, it declines as household production is replaced by market production when economies transition from agriculture to industry, but then eventually it rises as the economy transitions towards services

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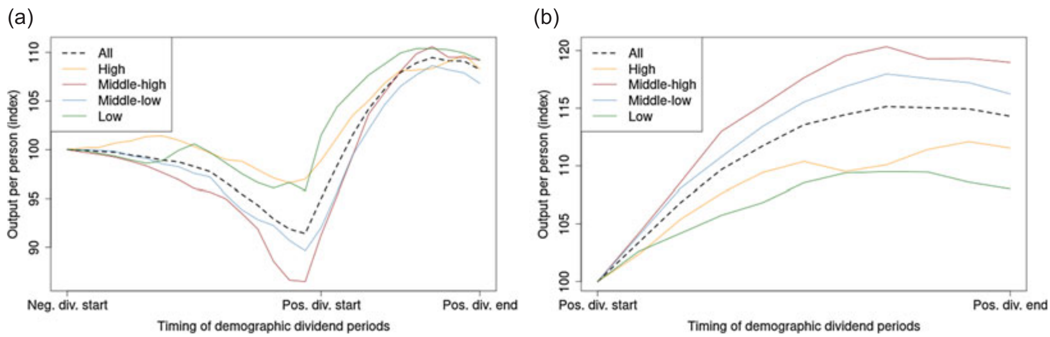

Negative and positive dividend periods — Positive dividend period only

Figure 1. The effect of the demographic dividend globally and by income group.

(Goldin, 1995). However, recent empirical evidence brings into question the existence and quantitative importance of the U-shape (Gaddis and Klasen, 2014).

Another shortcoming of the analysis is that it encompasses very long periods of time during which many important policy reforms were implemented. For instance, in many of the countries considered, a modern pension system was not introduced until the country was well into its demographic transition (e.g. 1908 in the United Kingdom). This means that the baseline simulations miss these important policy reforms and how they may have interacted with the demographic transition. This may be particularly problematic for the analysis with intergenerational redistribution, which assumes a constant pension replacement rate throughout the entire transition. As this paper focuses on breadth by covering a large number of countries, as opposed to covering one or few countries in-depth, this shortcoming is acknowledged, but is seen as necessary in the present context.

A similar limitation arises from the assumption of constant parameters within countries. That is, certain parameters, such as the capital share (α) may have very well changed over the course of the demographic transition in some or all countries.[5] This creates another layer of uncertainty about this paper's estimates of the dividend. To some extent, the sensitivity analysis addresses this concern by showing that most parameters do not change the paper's estimates of the dividend significantly. But nevertheless, this is another limitation of the paper.

4. Results

This section presents the results of the model simulations. First, country-specific estimates of the demographic dividend's growth effect are discussed. Second, the mechanisms driving the results are explored. Third, the role of intergenerational redistribution, controlled by γ, is taken into account. Fourth, a correlational analysis explores which countries tend to have bigger dividends. Fifth, a sensitivity analysis is conducted showcasing the role of different parameters behind the results. Sixth, the size of the dividend during the post-World War 2 baby boom is discussed. Finally, a number of robustness checks are carried out.

4.1 Estimates of the dividend

The impact of the demographic dividend on economic growth is illustrated by Figure 1. This figure shows how output per person would have evolved on average if the demographic dividend had been the key driver of growth. To see how this counterfactual is exactly constructed, refer to Section 3.4. Table 1 captures the key numbers behind the figure.

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Table 1. Summary of results by country group

Category	Pos. div.	Neg. div.	Max. cum. div.	Med. cum. div.
Global	0.40	−0.12	9.5	7.9
Middle East and North Africa	0.51	−0.13	13.4	9.8
Sub-Saharan Africa	0.22	−0.11	8.6	6.6
Latin American and the Caribbean	0.47	−0.15	10.5	8.0
Europe and Central Asia	0.17	−0.01	8.6	4.7
South Asia	0.46	−0.08	14.5	12.2
East Asia Pacific	0.57	−0.22	8.5	6.3
North America	0.19	−0.01	−0.2	−9.8
Low income	0.26	−0.09	10.4	9.2
Lower-middle income	0.45	−0.14	8.7	6.5
Upper-middle income	0.51	−0.17	10.6	8.1
High income	0.30	−0.04	9.7	8.1

Note: This table shows estimates of the demographic dividend by region and income category. “Pos. div.” and “Neg. div.” refer to the median annual growth effect of age structure during the positive and dividend periods, respectively. “Max. cum. div.” and “Med. cum div.” refer to the maximum and median cumulative dividend during the positive dividend period, respectively. All numbers are averages across countries.

To begin, note from Table 1 that the global average positive dividend is 0.40 percentage points. What this means is that, on average, annual growth rates are lifted by 0.40 percentage points during the positive demographic dividend. This effect accumulates over the years and pushes global average income per capita up to about 9.5% above where it otherwise would have been. This number is called the “maximum cumulative dividend.” It is also visible on Figure 1a: the global (dashed black) line rises about 10% above baseline at its maximum during the positive dividend period. Table 1 also shows a “median cumulative dividend,” which is just the median size of the cumulative dividend during the positive dividend period.

The details of the dynamic effects of the dividend can be seen in Figure 1. One can see in Figure 1a that there is initially a negative effect on output per person from the negative dividend: this is when dependency ratios are increasing at the beginning of the demographic transition. Once this negative effect subsides, the positive effect more than makes up for it. Figure 1b rebases output per person to 100 at the beginning of the positive dividend period (when dependency ratios start declining), and it shows that output per person rises as much as 15% thanks to the positive dividend. About 5% of which is to make up for the negative dividend, and the remaining 10% raises output per capita above baseline.

Table 1 and Figure 1 both show the effect of the dividend broken down by country income group. Table 1 also breaks the results down by world region. There is substantial variation in the size of the dividend across world regions and income groups. Low-income as well as Sub-Saharan African countries experience a dividend of only 0.22–0.26 percentage points—about 60% of the global average. A potential reason for this might be that these countries are experiencing much higher population growth rates during their demographic transitions. As Reher (2011) points out fast population growth can overwhelm the ability of the population to emigrate and the capacity of the local economy to create enough jobs, thereby suppressing the positive effects of the dividend. Historically, out-migration was an important outlet for growing populations during the demographic transition. The strongest dividends, on the other hand, are seen in middle income countries and East Asia Pacific. As Section 4.4 suggests, this may be due to the relatively fast transition that these countries experienced, which is associated with more extreme movements in dependency ratios and thus higher values of the dividend. Figure C7 in the Online Appendix

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shows how the share of workers in total population changed over the course of the positive dividend by country group. It is apparent that countries with larger favourable movements in worker share experienced larger positive dividends.

Table D3 in the Online Appendix shows the detailed results for each country separately. As is apparent from Figure 1, the growth effect of the dividend varies over time. For this reason, Table D3 shows several quantiles of the dividend growth effect distribution—separately for the positive and negative dividend periods. For instance, looking at Angola ("AGO"), it can be seen that in the periods where the demographic transition exerted a positive effect on growth, the median effect was to increase annual growth by 0.18 percentage points. The table also shows the 25th and 75th percentiles as well as the maximum effect, as the positive growth effect is not the same in every year. The same information is shown for the negative growth periods suggesting that Angola's growth rate was about 0.09 percentage points lower during these periods according to the median estimate. Note that some countries are missing estimates for the negative dividend because their fertility decline preceded or coincided with their mortality decline according to Delventhal et al. (2021). Therefore, these countries did not experience a period of declining worker share. Table D3 also shows the maximum and median cumulative dividends ("Max. cum. div." and "Med. cum. div.") for each country.

In addition to the annual and cumulative dividend estimates, Table D3 also presents estimates of the fraction of total economic growth that is explained by age composition during the positive demographic dividend periods ("% age"). The balance is what is explained by the human capital and technology channel. As it can be seen, the estimates suggest that during the positive demographic dividend periods, age structure contributes on average 9.5% of economic growth rates. This means that changes in age structure are an important force behind the demographic dividend even if the human capital channel is shut down. But indeed, human capital is a more important driver of growth overall.[6] Note that the changes due to age structure also include changes in capital accumulation and labour supply due to developments in age structure. The size of the three possible ways for age structure to affect growth (direct effect, capital accumulation, labour supply) is decomposed in Section 4.2 below. Similarly, the human capital and technology channel also captures the effect of human capital and technology on capital accumulation and labour supply.

Overall, these results are largely in line with the previous literature. The annual dividend of 0.40 percentage points is similar in magnitude to the 0.34–0.59 percentage points found by Lee and Mason (2006), to the 0.30–0.40 percentage points from Eastwood and Lipton (2011), to the 0.40–0.60 percentage points from Mason et al. (2016), and to the 0.20 percentage points from Ashraf et al. (2013). The contribution of demographic changes to economic growth during the dividend is estimated as 9.5% on average in this paper, which is somewhat lower than the 20% estimate for the same number by Kelley and Schmidt (2005). However, there are some papers that have lower or higher estimates. For instance, papers like Crespo Cuaresma et al. (2014), Rentería et al. (2016), Baerlocher et al. (2019), Lutz et al. (2019) argue that the dividend is zero, and Bloom and Williamson (1998) find a dividend that is substantially larger, approximately 1.52 percentage points, than what is estimated here. Nevertheless, this paper's estimates fit neatly in the range seen in the existing literature.

4.2 Mechanisms behind the results

How exactly is the demographic dividend pushing GDP per capita up? To answer this question, one can look at the dynamics of the different drivers of GDP per capita in the model. Dropping time subscripts, GDP per capita is given by $Y/N = A(K/N)^{\alpha}(L/N)^{1-\alpha}$, where N is total population and L is effective labour, as defined in Section 2. This can be readily decomposed into

$$\frac{Y}{N} = A\left(\frac{K}{N_w}\right)^{\alpha}\left(\frac{L}{N_w}\right)^{1-\alpha}\frac{N_w}{N},$$

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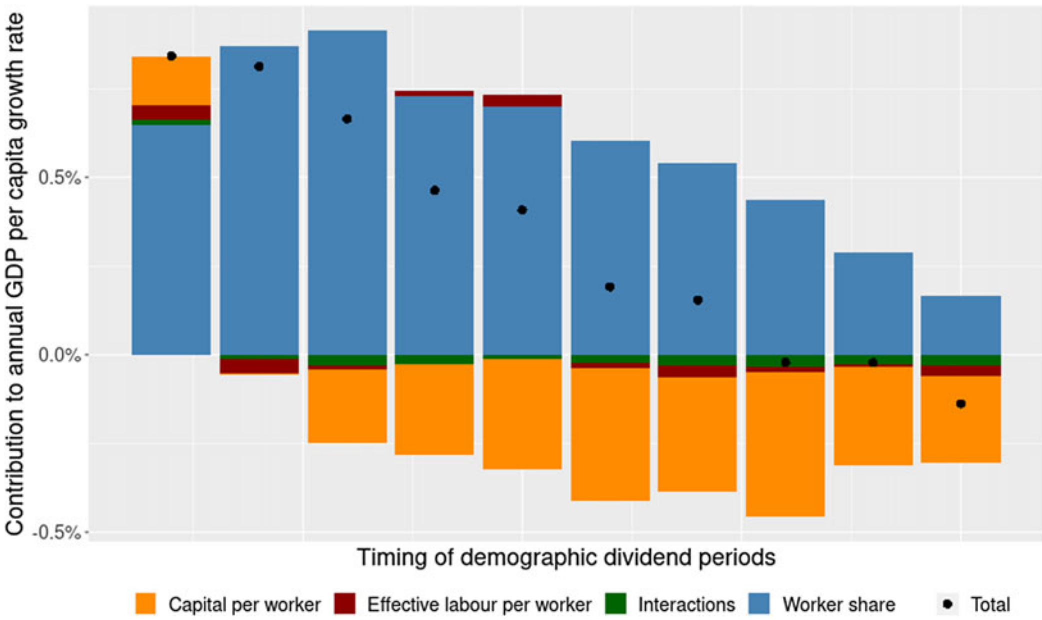

Figure 2. The factors behind dividend-driven growth.

where N_w is the number of working-age individuals. There are thus four possible drivers of GDP per capita: TFP (A), capital per worker (K/N_w), effective labour per worker (L/N_w), and the worker share (N_w/N). Given that in the counterfactual simulations $\epsilon = 0$, TFP growth is shut down, so that leaves three potential channels for dividend-driven growth.

Following the above equation, Figure 2 decomposes the growth generated by the positive demographic dividend into the three potential channels plus their interactions.[7] It is apparent that the key positive contributor to growth is worker share (N_w/N). Initially, the positive contribution by worker share is reinforced by capital per worker and to a lesser extent effective labour per worker. But the contribution of these channels turns negative in later periods. Capital per worker, in particular, is diluted due to the fast-growing working-age population. Accounting for this capital dilution is important for getting an accurate estimate of the dividend.

Aggregate variables such as population (Figure C8a) and capital stock (Figure C8b) are increasing during the positive dividend periods. Despite this, the share of workers in total population is, by definition, still increasing (Figure C8c), i.e. dependency ratios are dropping. This has a direct positive effect on output per person. In contrast, the increase in capital stock is eventually offset by the rising worker population diluting capital per worker. As capital becomes more scarce, its price increases (Figure C8d). Effective labour per worker does not move in a quantitatively significant way. But to the extent it does move, it eventually declines. This is because labour becomes more abundant due to population growth (Figure C8e), which pushes down wages (Figure C8f) and reduces the endogenous labour supply (Figure C8g).

4.3 The role of intergenerational redistribution

Are the growth effects of the demographic transition sensitive to intergenerational redistribution? Figure C9 shows the dynamic effect of the dividend with and without intergenerational redistribution. A replacement rate of 60% is considered for these simulations, which is around the OECD average (OECD, 2022). Table D4 shows a summary of the numbers behind the figure. It is apparent from Figure C9a that intergenerational dampens the negative part of the demographic dividend. There is not as much damage to GDP per capita growth during these high dependency ratio years

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Table 2. Univariate correlation between DT characteristics and the dividend

Variable	Pos. div.	Neg. div.	% age	Max. cum. div.
DT start	0.0731	−0.3816	−0.0059	−0.0673
DT length	−0.1869	0.3380	−0.0657	−0.0450
Pop. multiple	−0.1042	−0.0438	−0.0435	−0.1279
Final OADR	0.2710	0.0322	0.0998	0.1855
Final YADR	−0.2624	0.0426	−0.0815	−0.1353
Final ADR	0.2402	0.0690	0.0966	0.1883

Note: This table shows correlations between dividend measures and demographic transition characteristics. The key takeaway is that countries with shorter transitions and more eventual ageing experience larger dividends. “Pos. div.” and “Neg. div.” refer to the median of the annual growth effect of age structure during the positive and dividend periods, respectively. “% age” refers to the contribution of age structure to overall GDP per capita growth during the positive dividend period. “Max. cum. div.” refers to the maximum cumulative dividend during the positive dividend period. “DT start” is the start date of the demographic transition. “DT length” is the length of the demographic transition in years. “Pop. multiple” is the ratio of population at the end of the transition to population at the beginning. “Final OADR,” “Final YADR,” and “Final ADR” are the old, young, and total age dependency ratios at the end of the transition.

with intergenerational redistribution. The pension system does seem to reduce the size of the positive dividend, however. This is particularly clear in Figure C9b. Overall, the combination of a weaker negative and weaker positive dividend give rise to higher cumulative dividends with intergenerational redistribution: the median cumulative dividend is around 14% with a pension system as opposed to only 10% without one. Whether labour or capital taxation is used to financed the pension system seems to make very little difference.

The weaker positive dividend in particular is driven primarily by a stronger negative response from labour supply to changes in the working-age population (Figure C9c). The response of capital accumulation, meanwhile, is not as starkly different from baseline (Figure C9d). This result dovetails the findings by Cigno (2008); Caliendo and Findley (2020); Gustafsson (2023) showing that the introduction of pension systems have labour supply effects.

A blanket replacement rate of 60% for all countries in all years is an oversimplification, of course. Unfortunately, it is difficult to find historical data on the pension replacement rates of a wide swath of countries, which would be required for more accurate estimates. However, for a selection of OECD countries, there is data on replacement rates for recent years (OECD, 2022).[8] Using this data to compare the baseline simulations for these countries ($\gamma = 0$) with a counterfactual where γ comes from the data yields slightly different results. As Figure C10 shows, if replacement rates are taken from the data, then the pension system does not dampen the negative dividend as much as before, however, it does help produce a stronger positive dividend. Overall, these two effects produce a cumulative dividend that is somewhat stronger than what was estimated with a blanket 60% replacement rate: a 12% cumulative median dividend relative to the 11% with $\gamma = 0.6$ (see Table D6). The average replacement rate for the 23 countries considered in this analysis is 66%, which suggests that more generous pension systems can magnify the size of the dividend slightly.

4.4 Correlates of the dividend

As Table 1 reveals, there is substantial variation in the dividend across countries. A question that then arises is what factors determine the size of the dividend. While a full-fledged analysis of this question is beyond the scope of this paper, it is informative to see how the model's estimates of the dividend correlate with a variety of variables.

To this end, Table 2 shows the univariate correlation between the different measures of the dividend and characteristics of the demographic transition such as its start date, length, the population multiple between the beginning and end of the transition, and the final dependency ratios at the end of the transition. The table reveals that countries with longer demographic transitions experience a weaker positive demographic dividend and a stronger negative dividend on average as

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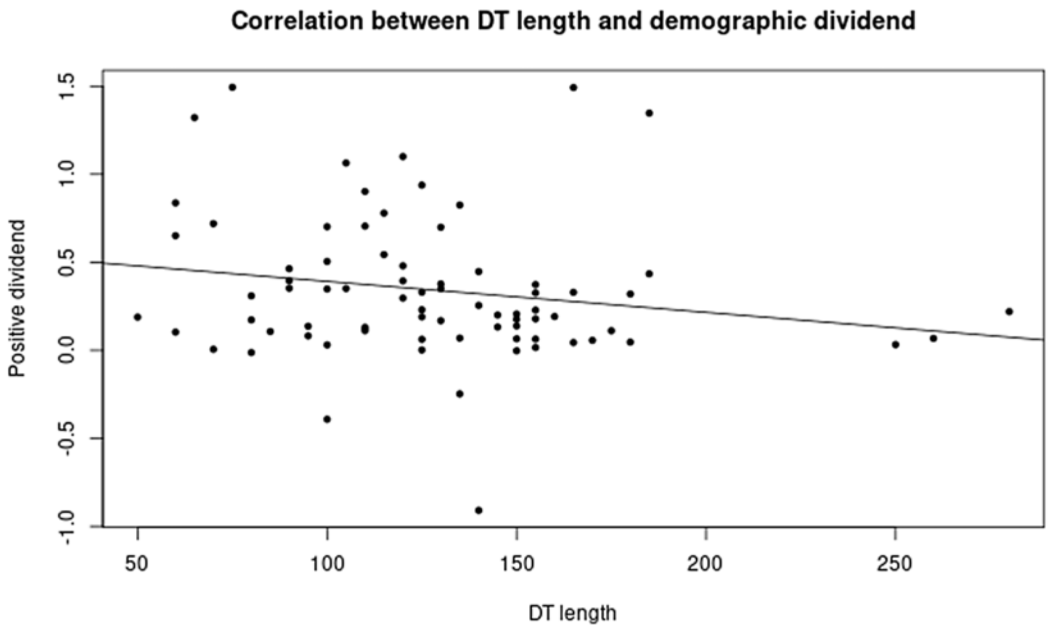

Figure 3. Univariate correlation of dividend and transition length.

also illustrated in Figure 3. This finding is in line with the results of Hahn and Park (2010), which are established in cross-country regressions. In addition, countries that end up with an especially old population (high OADR) at the end of the transition experience higher positive dividends. Overall, more "extreme" transitions (whether measured by speed or the degree of ageing at the end) are associated with stronger dividends during the transition. Finally, Table 2 also reveals that countries that started the transition earlier experienced worse negative dividends, and that the relative importance age structure and human capital in driving growth is not strongly associated with characteristics of the demographic transition.

A multivariate correlational analysis is not carried out as the potential explanatory variables (e.g. demographic transition start, length, final dependency ratios) are rather strongly correlated with each other (see Table D7) making it hard to tease out their individual contributions in a multivariate settings due to multicollinearity issues.

4.5 Sensitivity analysis

The results' sensitivity to different parameter values is shown in Table D8. The simulation is re-run with each parameter perturbed by $\pm 10\%$. There are three exceptions to this rule. First is the quantity-quality trade-off parameter, σ. As discussed in Section 3.3, the baseline value for σ is 0.03 following the literature. But some papers in the literature find no evidence for the quantity-quality trade-off. So instead of merely perturbing σ by $\pm 10\%$, the sensitivity analysis considers $\sigma = 0$ and $\sigma = 0.06$—that is completely shutting down the trade-off and doubling its size, respectively. Second, the Frisch elasticity parameter, ψ, is modified to the minimum and the maximum of its empirical range as per Whalen and Reichling (2017), which are 0.27 and 0.53 whereas the baseline is 0.40. Third, the labour disutility parameter is also perturbed more than $\pm 10\%$: it is halved to 6.5 and doubled to 26 from its baseline value of 13. This roughly corresponds to the range considered by Fanti and Spataro (2006).

Overall, Table D8 shows that the results are remarkably stable even in the face of different parameter values. The results of the sensitivity analysis give a hint of how different parameters are driving the results. Higher capital share (α) weakens the dividend, probably because if labour is a more important input, the dependency ratios matter more for output. More LTO (higher β)

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increases the dividend. If capital depreciates more slowly (lower δ), the dividend is smaller. Higher disutility of labour (ϕ) reduces the dividend as presumably households adjust their labour supply more strongly in response to fluctuations in worker share, which accentuates the negative effect of labour supply on the dividend. A higher Frisch elasticity (ψ) increases the dividend. More risk-averse households (higher θ) lead to a lower dividend. The sensitivity of human capital investment to technological progress (χ), the sensitivity of technological progress to aggregate human capital (ϵ), the cost of human capital (κ), and the size of the quantity-quality trade-off (σ) have no meaningful effect on the dividend.

4.6 The baby boom

As explained in the last paragraph of Section 3.4, the effect of the baby boom after World War 2 on GDP per capita growth can also be estimated using the data generated by the model. This is shown in Table D9. The average size of the median baby boom dividend is around 0.26 percentage points, which is largely in line with the average size of the pre-war demographic dividend for Europe and Central Asia in Table 1. To some extent, the Czech Republic, France, and Spain have higher baby boom dividends than pre-war dividends. With the exception of Spain, these are all countries that had a relatively sizeable post-war baby boom according to Van Bavel and Reher (2013). Meanwhile, Denmark, Finland, Sweden, and the United Kingdom have similar or smaller baby boom dividends compared to pre-war times. These happen to be countries with relatively small post-war baby booms (Van Bavel and Reher, 2013). Therefore, in accordance with intuition, countries with bigger post-war baby booms experienced larger dividends. However, the size of the baby boom dividends overall are in the same ballpark as the size of the "traditional" demographic dividends.

The contribution of baby boom age structure changes to overall GDP per capita growth is approximately 9.0% in this sample of countries ("% age" column in Table D9). In most countries, the contribution of demographics is similar for the pre-war dividend and the post-war baby boom. Three notable exceptions are the Czech Republic, France, and Spain whose post-war growth relied more heavily on demographics than their pre-war growth. In the Czech Republic, in particular, more than half of post-war growth is attributable to the baby boom.

4.7 Age-specific schooling costs

It is reasonable to assume that schooling may get more expensive at older ages. Would such a mechanism affect the results? Figure C11a shows the baseline result and a counterfactual simulation in which the per-period cost of schooling (κ) is raised by 50% for ages 10–19. As is apparent from the figure, more expensive schooling at older age at this level does not alter the main results in an important way.

4.8 Differences in education quality

The quality of education differs across countries. Would taking this into account alter the main results? To answer this question, an alternative simulation is run where the contribution of human capital to the production function and TFP is scaled using an education quality parameter, $q \in (0, 1]$, as follows:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$$
$$= A_t K_t^{\alpha} \left(\sum_{j \in \mathcal{A}_t} h_j^q N_{t,j} \right)^{1-\alpha}$$
$$A_t = \left(\sum_{j \in \mathcal{A}_t} h_{j,t}^q N_{j,t} \right)^{\epsilon}.$$

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The parameter q is inferred from data. In particular, human capital quality data is taken from Lee and Lee (2024). A quality factor for human capital is backed out from this data set by dividing quality-adjusted human capital by quantity-based human capital (averaged across 1985–2015). The resulting quality factor is then rescaled so that its maximum value is 1. The highest quality factor, by definition, is then 1 and it is attained by Japan, while the lowest one is 0.65 attained by Ghana. The mean is 0.87. This quality factor is used as the estimate for the parameter q.

Figure C11b shows that introducing quality adjustment for human capital in the model in this way does not alter the estimates of the demographic dividend at all. The line for this alternative simulation lies exactly on top of the baseline simulation's.

5. Conclusion

Using a modelling approach novel to the literature, this paper evaluates the size and drivers of the demographic dividend on a country-by-country basis. The key findings are that the demographic dividend lifts annual GDP per capita growth rates by 0.40 percentage points on average, and 9.5% of total GDP per capita growth during the demographic dividend period is driven by age structure. The size of the dividend varies substantially across countries with lower income countries experiencing lower dividends. It is also observed that countries with more rapid and more extreme changes in age structure have higher dividends.

The size of the dividend estimated here, a global average of 0.40 percentage points, is largely in line with Lee and Mason (2006) and Eastwood and Lipton (2011), but it is substantially lower than the estimates of Bloom and Williamson (1998). Thus, the findings are closer to the lower end of the literature. The aforementioned papers also find regional variation in the size of the dividend which is roughly in line with what is found in this paper: relatively high dividends in Asia, Latin America, and the Middle East and North Africa, and relatively low dividends in Sub-Saharan Africa. Kelley and Schmidt (2005) quantify the total contribution of demographic changes to GDP per capita growth, and their findings of a 21.0% contribution is quite a bit higher than this paper's finding of 9.5%.

The findings of this paper imply that the demographic dividend certainly helps lift GDP per capita growth rates, but it is by no means a silver bullet. A country experiencing a demographic dividend should make sure that accompanying human capital investments are made in order to maximise economic growth. Conversely, given the relatively modest size of the dividend (a global average of 0.40% per annum), completing the demographic transition per se is not going to be a major culprit for declining GDP per capita growth in most countries.

Acknowledgements. I would like to thank four anonymous referees, Richard Grossman, David Kuenzel, and participants at the International Workshop on Economic Growth and Macroeconomic Dynamics at the Sapienza University of Rome, the 2022 Southern Economic Association Annual Meeting, the 2023 Eastern Economic Association Annual Meeting, the 2023 Midwest Economic Association Annual Meeting, the DEM Workshop on Ageing, Culture, and Comparative Development at the University of Luxembourg, and the Annual Conference SITES 2023 at the Parthenope Universityof Naples for their helpful comments and suggestions.

Supplementary material. The supplementary material for this article can be found at http://dx.doi.org/10.1017/S1365100525100394.

Competing interests. The author declares none.

Notes

1 This accounting effect refers to the fact that according these authors age structure only affects GDP per capita, not GDP per worker. Therefore, the impact of age structure on GDP per capita is purely mechanical.

2 Note that according to the estimates of Delventhal et al. (2021), only one country with non-missing data fully completed its demographic transition before 1950: Austria in 1941. Due to lack of pre-1950 population age structure data, this paper assumes that Austria's transition ended in 1950, and uses 1950 data as its final age structure.

3 The YADR is defined as YADR = (number of 0 – 19 year-olds) / (number of 20 – 64 year-olds). An analogous quantity, the OADR, is defined as OADR = (number of 65+ year-olds) / (number of 20 – 64 year-olds).
4 The countries include the United States, Austria, France, the Czech Republic, Finland, the United Kingdom, Sweden, Denmark, and Spain. These countries all had a baby boom volume index of 2 or higher according to Van Bavel and Reher (2013).
5 For evidence on capital share changes, see e.g. Bengtsson and Waldenstrom (2018).
6 Growth accounting suggests that human capital per person only explains 20% of growth, at least in the United States over the 1950-2007 period (Fernald and Jones, 2014). But note that the "human capital" channel in this paper incorporates three different factors: human capital per person, population size, and technological progress.
7 This is done by converting the above formula with the potential drivers into growth rates using a logarithmic approximation as $g_{Y/N} \approx g_A + \alpha g_{K/N_w} + (1-\alpha) g_{L/N_w} + g_{N_w/N}$, where g_X denotes the percent growth rate of variable X.
8 For a list of these countries, see Table D5.

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Cite this article: Zélity B (2025). "Estimating the growth effect of the demographic dividend." *Macroeconomic Dynamics* **29**(e127), 1–24. https://doi.org/10.1017/S1365100525100394