The cost of population growth in the UK

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Summary

The cost of extending provision of infrastructure, equipment and skilled service providers to additional population was estimated from UK historical expenditure accounts. It was found that each additional person requires £165,000 to be spent on housing, infrastructure, equipment and training, to extend to them the services, living standard and employment opportunities of current UK residents. This cost is borne by existing residents, through a higher cost of living. At the current population growth rate, this corresponds to over £1,000 per person each year, or £2,300 per household. Between 1960 and 2010, maintenance of fixed capital (turnover) has cost 13.36% of UK GDP; its expansion has cost 6.89% of GDP per 1% population growth. Expanding infrastructure and equipment capacity at the current population growth rate of 0.7% p.a. consequently requires 4.8% of GDP per annum.

Applying these figures to Office of National Statistics projections from 2010 to 2050, the Low Population projection (0.24% population growth per annum) would cost 1.7% of GDP or £26 billion per annum; the Principal (medium) projection (0.58% population growth per annum) would cost 4.0% of GDP or £67 billion per annum; and the High Population projection (0.86% population growth per annum) would cost 5.9% of GDP or £106 billion per annum. The cumulative cost of UK population growth from 2010 to 2050 adds up to £1.1 trillion, £2.7 trillion and £4.2 trillion for the Low, Principal and High projection respectively, in 2011 values assuming constant per capita GDP. To 2100, the cumulative cost would be £1.1 trillion, £5.5 trillion and £11.6 trillion respectively. This expenditure is required simply to maintain, not improve, current standards. It is not offset by any improvement in demographic age structure, and does not include the extra cost of essential food and energy imports.

Introduction

Since 1997, the UK's population growth rate has increased sharply, from 0.26 per cent per annum to 0.68 per cent per annum. The number of people added to the population was around 150,000 in 1997 and 430,000 in 2012. This paper aims to estimate the impact on the UK economy from this acceleration of growth rate. It then considers the cost implications of future population policy and outcomes, based on three population projections generated by the Office of National Statistics (ONS).

The costs assessed in this study are those required for providing the durable assets needed by additional people. The quality of life a nation may provide for its citizens depends greatly on its stock of durable man-made assets, in addition to its endowment of natural assets. Man-made assets include all forms of infrastructure, from private housing, industrial and commercial structures to hospitals, utilities, transport and public amenity. In addition, they include all forms of equipment, from domestic appliances to vehicles and major industrial installations. Further, the supply of professional and trade services implies a prior investment in training, which also creates a durable asset.

Each of these durable assets has a limited useful lifespan, and hence a proportion of total economic activity each year must be used for asset acquisition, to maintain the stock. In a stable population, the annual investment would be inversely proportional to the lifespan of the asset class: 100 divided by the lifespan in years equals the annual percentage turnover. Thus, if power stations last for 40 years, on average 2.5 per cent of them would need to be replaced each year to maintain a stable stock. If municipal buses are in service for 10 years, 10 per cent of the fleet would need to be purchased per year.

It is important to recognise that the total value of all durable man-made assets is several times greater than total annual GDP. In any one year, a society can only afford to provide a fraction of the stock. Durability allows many years' worth of asset acquisition to be enjoyed at any one time. Quality of life therefore depends greatly on the durability of the things we create.

Theoretical approach

The direct cost of population growth rate is measured as the increased rate of acquisition required to expand the stock of durable assets, in addition to maintaining the stock. It is assumed that a population increase of one per cent means that maintaining a constant quality of life requires an additional one per cent of all assets, including *inter alia* hospitals, classrooms, power stations, factories, roads, vehicles, televisions, microwave ovens, nurses and electricians.

This is an oversimplification of reality, but errs on the conservative side. Some items are 'lumpy', so that an extra unit creates overcapacity for some time, but is usually delivered after inadequate capacity has been carried for some years. Over time and across all asset classes, these costs level out. Some items may have economies of scale, but these are largely exhausted at population densities far lower than found in the UK. Many items have diseconomies of population density: it is more costly per added person to provide transport when extra capacity means tunnels and fly-overs, to provide water when it must be regionally redistributed and recycled, to build thirty-floor structures than three, or to equip fire services to protect life and limb in a high-rise landscape. Globally, the need for climate change mitigation measures, due to overloading of the atmosphere's capacity to process gaseous waste from human activities, is a significant example of increasing costs of human density.

Growth may also increase costs by shortening the lifespan of installations, either by requiring the land they occupy to be reallocated or by requiring them to be replaced with a higher-capacity version. These additional costs of growth are ignored in the current analysis, although they are in part accommodated in historical spending patterns.

The cost of population growth is disproportionately higher than the rate of growth itself. For instance, a cost-weighted average lifespan of all infrastructure is in the order of 50 years, implying a replacement need of two per cent of the total stock per annum. A population growth rate of one per cent per year implies the need to expand the stock by one per cent in that year, in order to keep pace with population growth. Consequently, society's burden of annual infrastructure acquisition is raised from two per cent to three per cent of the existing stock, a 50 per cent increase.

Similar calculations can be made for other categories of assets. If trained professionals on average spend 33 years in the workforce after graduation, a stable population would need to graduate 3 per cent of the workforce in that profession annually to replace retirees. If that population suddenly started to grow at 1 per cent per annum, it would need to graduate 4 per cent of the workforce: 3 per cent to replace retirees plus 1 per cent to expand the workforce. This is a 33 per cent increase over the burden carried by a stable population.

The result is that the percentage increase in annual burden for each per cent growth is equal to the working lifespan in years. Thus, for the examples we have given above, compared with a stable population, a one per cent per annum growth rate implies increasing expenditure on power stations by 40 per cent, on buses by 10 per cent, on university training by 33 per cent, and similarly for all other classes of assets.

In reality the picture is a little more complex. A steadily growing population has a lower need to replace retired assets, because the oldest cohort of any asset class is smaller than subsequent cohorts, and this reduces the retirement rate relative to the total stock. Over the range of population growth rates likely to be sustained for more than a few years (0 – 3 per cent) this youthfulness of the asset stock reduces the net burden of capacity expansion by a factor between 25 and 45 per cent, depending on lifespan and growth rate (O'Sullivan, 2012). However, as discussed above, several factors may have the opposite effect, with growth leading to an increased rate of turnover or increased cost per unit of additional capacity.

Methods

The UK expenditure on durable items was collated from national accounts of Gross Fixed Capital Formation (GFCF) and Household Final Consumption Expenditure. Expenditure values were expressed in purchase price parity with a base year of 2008. Annual expenditure and GDP were converted to per capita figures using the population estimate for each year. This simplified the collation of data across multiple years and the comparison of different periods of time. Line items were grouped by estimated lifespan, as given in Table 1. The assumed lifespans are considered conservative (for example, many buildings and structures are in use for much longer than 50 years), hence the overall estimates of cost represent the lower end of the likely range. In addition, the expenditure on tertiary education was included (OECD, 2012), using an average working lifespan of 35 years, estimated from the workforce participation and unemployment rate of tertiary-qualified people (World Bank, 2012).

The percentage of each lifespan category required to be added each year was estimated assuming that the age structure of the asset inventory matched past population growth. The proportion to be retired in any year was calculated from the population one lifespan ago divided by the sum of annual population estimates from that year to the current year. The calculated retirement rates are listed in Table 1. These are slightly smaller than the proportion that would apply in a stable population (2 per cent, 2.87 per cent, 5 per cent, 6.67 per cent, 10 per cent and 20 per cent respectively) due to the dilution of the oldest cohort by larger younger cohorts.

Table 1. Categories of expenditure assigned to estimates of lifespan of assets acquired, and the annual retirement rate (per cent of total stock to be replaced) assumed for each lifespan group.

Expenditure items	**Useful lifespan of assets**	**Annual retirement rate**
Dwellings, buildings and structures	50 years	1.85 %
Tertiary education	35 years	2.78 %
Furnishings and household equipment, building maintenance and renovation	20 years	4.87 %
Transport equipment, other machinery equipment and cultivated assets	15 years	6.53 %
Other items of household consumption listed as durable goods	10 years	9.85 %
Items listed as semi-durable goods	5 years	19.83 %

To obtain the proportion of the asset stock to be acquired each year, the population growth rate for the period in question was added to these turnover rates. The value of the total asset stock was then estimated from the actual expenditure, and the cost of capacity expansion calculated as this stock value multiplied by the population growth rate.

In the first instance, it was assumed that the actual expenditure on durable assets was sufficient to replace retired stock and expand the stock at the same rate as population growth. As an example calculation, the recorded expenditure on buildings and structures in the decade 1998 to 2007 was £2,298 per person per annum, in 2008 pounds. The required acquisition rate was calculated to be 2.30 per cent of the total stock, comprising 1.85 per cent for replacement and 0.45 per cent being the population growth rate per annum over that period. Consequently the value of the total stock of buildings and structures is estimated to be 2298/0.023 = £99,974 per person. Thus, each additional person requires about one hundred thousand pounds of additional buildings and structures. Spread across the whole population, the cost attributable to population growth was £449 per person per annum, solely for additional buildings and structures.

The question remained whether the actual expenditure was sufficient, insufficient or surplus for keeping pace with population growth. This was addressed by comparing the calculations over different time periods. The longer the period considered, the more likely that total expenditure matched that required for the standard of living actually achieved.

Disaggregated expenditure data were not available prior to 1997. Estimates based on the total expenditure on GFCF were found to match estimates using the disaggregated data for the same time period, when turnover rate was adjusted to 1.94 per cent, representing an average lifespan of 47.5 years. This implies that the overestimation of cost of some less durable items included in GFCF approximately compensated for the omission of costs from durable and semidurable household consumption, and tertiary education expenditure. The estimates based on GFCF were used to compare expenditure on durable asset capacity from 1960 to 2011.

The cost of capacity expansion derived from the above analysis was applied to three projections of the UK population published by the Office of National Statistics. The three projections could thus be compared in relation to the percent of GDP required for capacity expansion, and the cumulative cost to 2050 and 2100.

Results

Expenditure on durable items was initially analysed for the year 2010. However, it was apparent that spending patterns had altered in response to the global financial crisis (GFC), and that 2010 was not typical of preceding years. Consequently, analyses were also made of expenditure over the decade 2001 to 2010 and the decade 1998 to 2007.

Table 2 summarises the analysis for the decade from 1998 to 2007. Spending on durable items accounted for 28.8 per cent of GDP over this decade. Assuming that this expenditure accounted for renewal of items retired at the end of their lifespan as well as expanding the total stock at the same rate as population growth, the total stock value was calculated to be 6.8 times the annual GDP. Consequently, the cost of expanding the stock was estimated to be 6.8 per cent of GDP per one per cent population growth. At the decade average population growth rate of 0.45 per cent, growth cost 3.06 per cent of GDP, or around £41 billion per annum (2008 values). The cost of providing for each additional person was estimated to be £145,716. When spread across the existing resident population, the burden was £654 per person.

Table 2. Average annual expenditure per capita on durable items, over the decade from 1998 to 2007, and the calculated expenditure attributable to growth in the stock of such assets to accommodate population growth. Monetary values are expressed in 2008 pounds.

Class of Expenditure Item	Assumed lifespan (years)	Expenditure £ per capita	Annual acquisition % of stock	Total value of asset stock £ per capita	Expenditure attributable to growth £ per capita
Buildings and structures	50	2,298	2.30	99,974	449
Post-secondary education	35	238	3.23	7,370	33
Household equipment & renovation	20	353	5.32	6,629	30
Transport and industrial equipment	15	1,196	6.98	17,135	77
Household consumption durable	10	917	10.30	8,902	40
Household consumption semi-durable	5	1,157	20.28	5,705	26
Total		6,158		145,716	654
Population growth rate – decade average			0.449		
GDP per capita – decade average		**£**21,370			
% of GDP		28.82%		682%	3.06%

In the year 2010, the analysis implied a cost of growth of 5.7 per cent of GDP per one per cent population growth. Over the decade 2001 to 2010, the estimate was 6.2 per cent. In the light of reduced expenditure in the years since the GFC, despite continuing increase in population growth rate, it was concluded that these estimates represented underspending.

Historical expenditure on fixed capital

In order to assess whether the decade prior to the GFC provided a reliable estimate of the cost of growth, it was compared with the time course of spending since 1960. Over this period, only the aggregate figure for spending on gross fixed capital formation (GFCF) was available. The analysis was calibrated to generate estimates very close to those of the disaggregated data, by adjusting the assumed lifespan to 47.5 years.

Expenditure on GFCF varied within a limited range between 1960 and 2010. It appeared to respond to population growth rate to some extent over most of that period, probably in response to emergent capacity constraints rather than a strategic recognition of the link. However, at both ends of this period expenditure and population growth trends diverged. Prior to 1968, expenditure on GFCF increased steadily as a proportion of GDP despite population growth declining. After 2007, the proportion of GDP spent on GFCF declined despite population growth continuing to rise. These anomalous periods were excluded so that the 40-year period 1968 to 2007 was taken as the benchmark, for which expenditure on GFCF was assumed to be sufficient to keep pace with population growth and technology change. The adequacy or excess of expenditure in individual years was evaluated relative to this benchmark.

Over the benchmark period from 1968 to 2007, UK population growth averaged 0.255 per cent per annum, and expenditure on GFCF averaged 15.12 per cent of GDP. It was calculated that maintenance of the asset stock required 13.36 per cent of GDP, while 1.76 per cent of GDP was expended on expanding the stock to accommodate population growth. The value of the total stock of fixed assets was estimated to be 6.89 times annual GDP, meaning that 6.89 per cent of GDP is required per one per cent of population growth, to expand capacity.

Figure 1 presents the time course for population growth and capital expenditure in the UK since 1960. A population growth surge extended from 1952 to 1973, peaking in 1963 around 0.7 per cent per annum. The population was approximately stable for the decade from 1974 to 1983. Growth resumed around 0.22 per cent in 1985 to 1988, moving to 0.27 per cent from 1988 to 1997. From 1997, population growth rate rose steadily to 0.72 per cent in 2010, matching the 1960s peak.

Gross fixed capital formation expenditure rose gradually to accommodate the increased population growth through the 1960s, and declined more gradually than population growth, resulting in a period of net gain in assets per capita during the 1970s. The return of population growth in the 1980s was not consistently supported by increased capital expenditure. A significant increase in capital expenditure from 1997 under the Blair government, representing around two per cent of GDP, was soon overtaken by the increased requirements of population growth. Since 2007, capital formation has reduced despite sustained high population growth. This represents an expanding deficit in infrastructure capacity and renewal that must progressively impact on UK productivity and quality of life. The shortfall from 2003 to 2011 represents a backlog of over £200 billion.

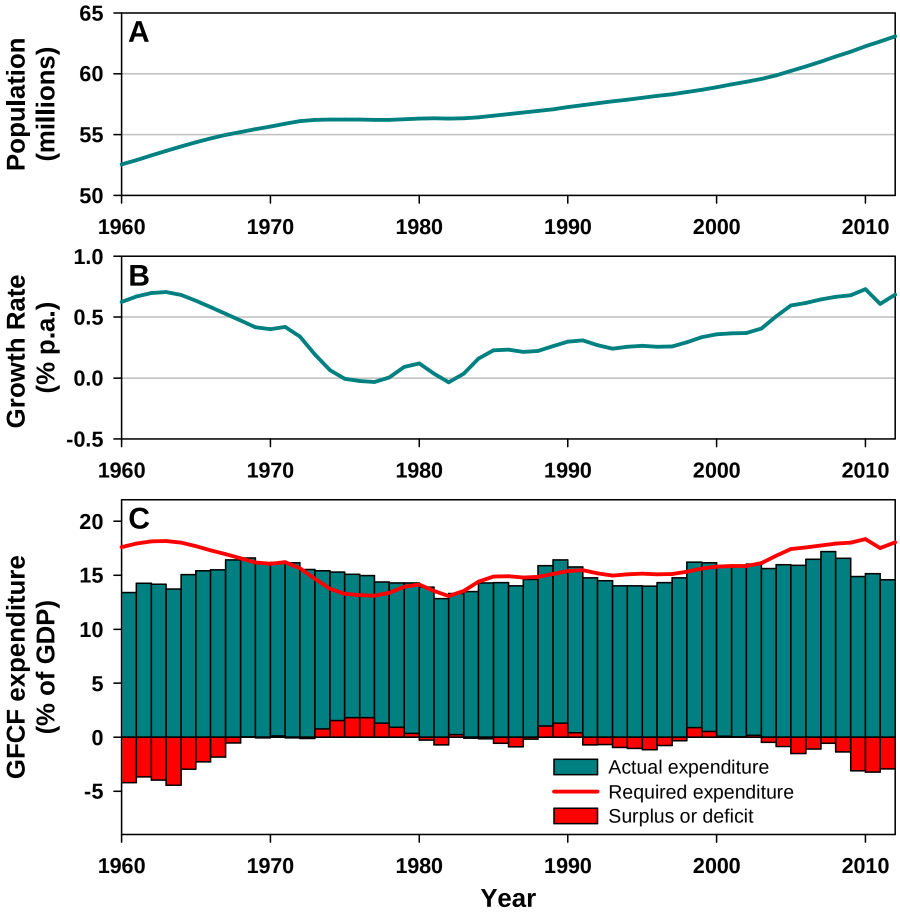

Figure 1. A: the population of the United Kingdom over the period 1960 to 2012. B: the population growth rate over this period. C: the expenditure on Gross Fixed Capital Formation (GFCF) as a percentage of total Gross Domestic Product (GDP), compared with the expenditure calculated to provide sufficient additional fixed assets for the additional population in each year.

Despite its many shortfalls, GDP per capita is the most commonly used surrogate for societal wealth, in international comparisons. However, in national economic commentary, it is the growth rate of aggregate GDP that is invariably reported. Population growth clearly diminishes the extent to which aggregate GDP growth enriches each citizen. Not only is the total GDP divided among a greater number of people, but the cost of accommodating the additional people is consumption that is not providing any goods or services to existing residents. Figure 2 shows the growth rate of GDP over the period 1993 to 2007, in comparison with the growth rate of per capita GDP, and the per capita GDP net of the cost of accommodating additional people.

Population growth rate accounts for the difference between GDP growth and per capita GDP growth. The change in population growth rate from year to year accounts for the difference between growth in per capita GDP and net per capita GDP. Hence the difference is greatest in periods when population growth is accelerating. However, as the effect on wealth is cumulative, these temporary differences have lasting impact. Over the decade from 1997 to 2007, GDP grew at an average rate of 3.2 per cent per annum, while GDP per capita averaged 2.73 per cent per annum and net GDP per capita averaged 2.45 per cent per annum.

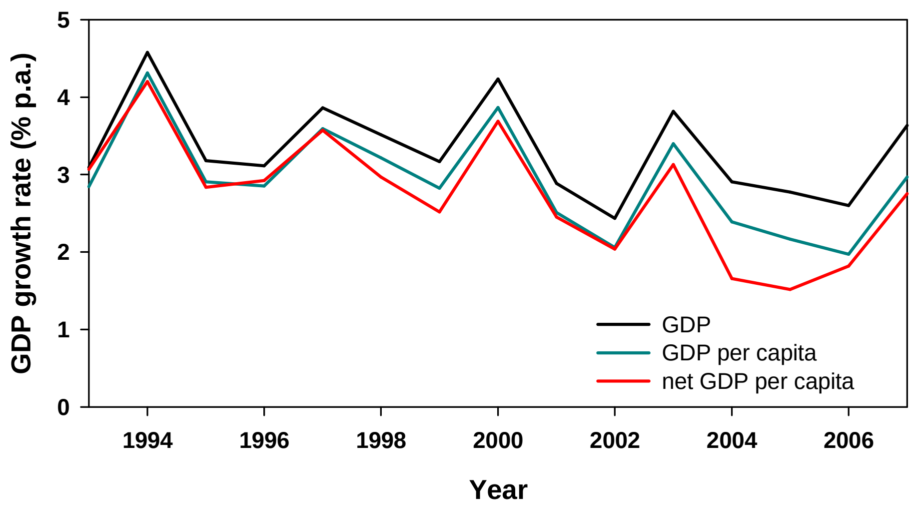

Figure 2. Annual per cent growth in UK GDP, in per capita GDP, and in the net per capita GDP after subtracting the cost of capacity expansion to accommodate additional people.

It is often claimed that population growth contributes to growth of the economy. However, it does so only to the extent that it delinks GDP growth from growth in wealth.

The cost of projected future population growth

The projections published by ONS apply from a base year of 2010. The characteristics of the principal, high population and low population projections are summarised in Table 3. It should be noted that these projections combine the effects of higher or lower total fertility rate (births per woman over her lifetime), net immigration numbers and life expectancy. They therefore provide limited information on the impact of a change in any one of these factors independent of the others. The ONS has published additional projections varying these three factors independently against the principal projection.

Table 3. The main parameters used to vary the three population projections published by ONS: levels of net migration (immigration minus emigration), total fertility rate (TFR) and expectation of life at birth (EOLB) for males and females. The conditions prevailing in 2010, at the start of the projection period, are also given. The current values for each parameter were incrementally changed to the target value, with target net migration applying from 2016, target TFR from 2026 and EOLB rising steadily to 2100.

	Net Migration (per year)	**TFR (births per woman)**	**EOLB (male/female)**
(2010)	*(252,000)*	*(1.98)*	*(78.5 / 82.6)*
Low population projection	140,000	1.64	81.1 / 85.5
Principal projection	200,000	1.84	92 / 95
High population projection	260,000	2.04	105 / 105

It is important to record that the conditions prevailing in 2010 are not typical of the UK's recent population course. Net immigration reached a record high in that year. Prior to 1990, it was typically under 100,000 per year, and was often negative. Total fertility rate has increased sharply since 2005, from an average of 1.66 prevailing between 2000 and 2005. While the principal projection anticipates some moderation of these recent levels, the low projection more closely represents the UK's historical trend.

Using the 2011 GDP, it was found that the capital cost of each additional resident requires £165,000 (2011 values) of expenditure on housing, infrastructure, equipment and training, to extend to them the services and living standard that current UK residents enjoy. This cost is born by existing residents, through higher cost of living. At the current population growth rate around 0.7 per cent, this corresponds to over £1000 per UK resident each year, or £2,300 per household.

Table 4 lists the costs of growth for each projection, over the period 2010 to 2050. Based on the growth rate averaged over this period, providing durable assets for additional people would cost 1.7, 4.0 and 5.9 per cent of GDP for the low, principal and high projection, respectively. The cumulative cost of UK population growth from 2010 to 2050, assuming constant per capita GDP from 2011, would be £1.0 trillion, £2.7 trillion or £4.2 trillion. This expenditure is required simply to maintain, not improve, current standards.

Table 4. The result of three population projections from 2010 to 2050 on population of the UK, and the cost of providing durable assets for the additional population. The cost for growth is that portion of expenditure on gross fixed capital formation (GFCF) attributable to providing extra capacity of infrastructure, equipment and high-level skills. Costs assume constant per capita GDP at the 2011 level, and are expressed as year 2011 pounds.

Projection	Population in 2050	People added 2010-2050	Average growth % per annum	% of GDP for growth	£ per capita per annum	Av. annual cost of growth £ billion	Cumulative cost 2010-2050 £ trillions
Low Population	68,591,399	6,329,399	0.242	1.67	402	25.68	1.05
Principal	78,445,223	16,183,223	0.579	3.99	961	66.64	2.68
High Population	87,733,927	25,471,927	0.861	5.93	1428	105.90	4.22

Figure 3 presents the three projections to the end of the century. The cost as a percentage of GDP is proportional to the annual population growth rate, while the monetary cost is proportional to the number of people added each year. The bumpiness in the high and principal projections are due to the rapid increase in births during the late 2000s, which will in turn increase births at the time these additional children become parents, and again when they become grandparents.

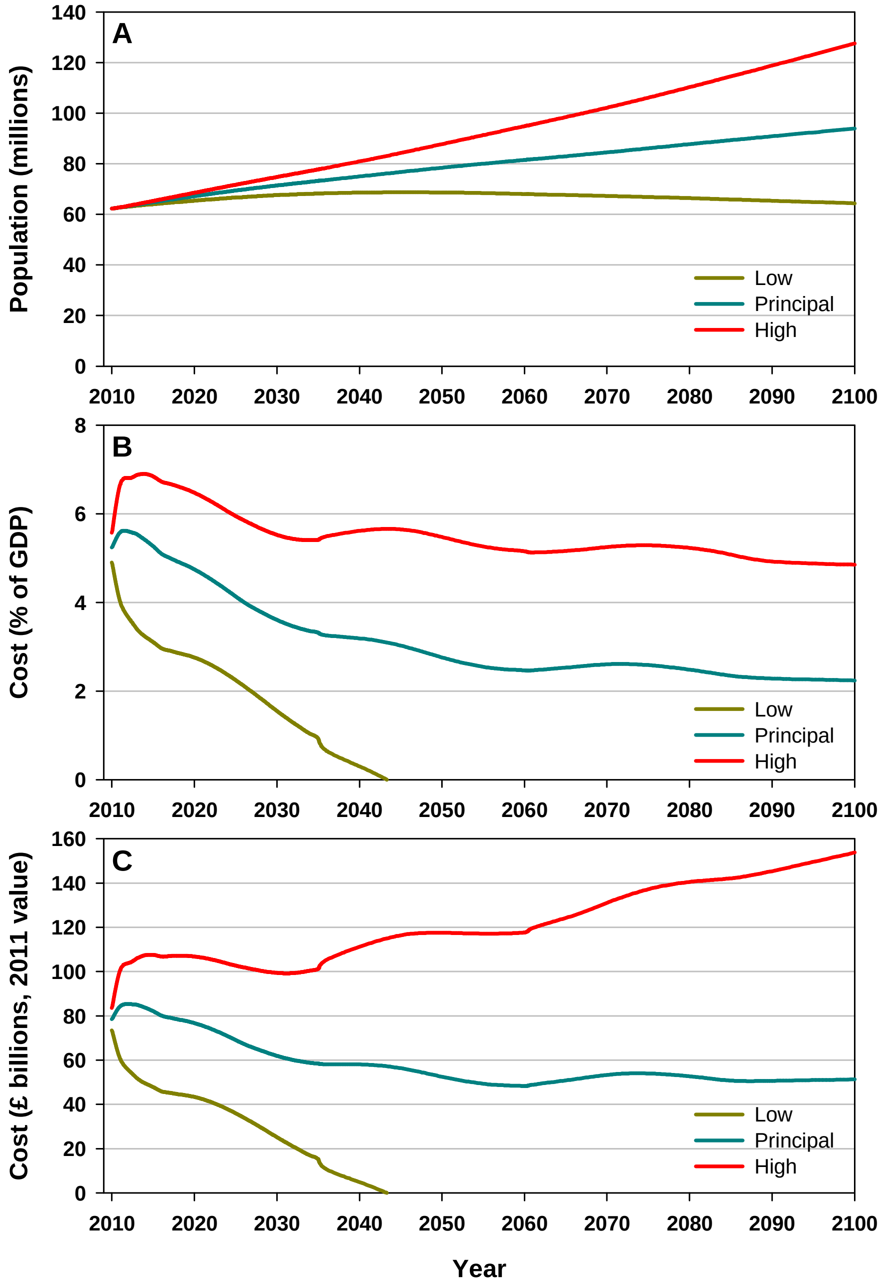

Figure 3. A: the UK population projected from 2010 to 2100, under the Low Population, Principal and High Population projections published by ONS. B: the cost of accommodating population growth, as per cent of GDP; C: the cost of accommodating population growth in billions of pounds per year, at 2011 values and assuming constant per capita GDP.

The cumulative cost to 2100 for the three projections would be £1.1 trillion, £5.5 trillion and £11.6 trillion respectively, in 2011 values assuming constant per capita GDP. If real per capita GDP increases, so would the cost, reflecting a higher standard of infrastructure, equipment and professional services available to a wealthier population. However, the affordability and opportunity cost would be similar, as is best reflected by the cost as per cent of GDP.

Discussion

Opportunity cost of population growth rate

In understanding the economic impacts of population growth, it is necessary to separate those of population level in relation to the natural resource base, demographic age structure and population growth rate. Advocates for a positive or neutral impact of population growth generally focus only on age structure, or on increased profits from expanding demand, not accounting for the externalised costs of dilution, degradation or liquidation of the legacy for the next generation. The costs of growth rate are rarely acknowledged. Those who have considered growth rate impacts find them to be strongly negative.

Coale and Hoover (1958) identified the effect of growth rate on saving and investment rate (supply of capital). In contrast, Sauvy (1958) emphasised the impact on demand for capital, specifically the need to divert available capital away from benefiting the existing population to the task of providing for additional people, just to stand still in terms of standards of living and employment availability. He termed this capacity expansion burden “demographic investment”. The name is a little deceptive, and perhaps dangerously so in the modern era when “investment” is typically funded through credit rather than saving. In Sauvy’s sense, “investment presupposes unpaid work” or at least work that is not rewarded in the immediate term. But it also implies a later reward that justifies the wait. The task of providing for added people is pure penalty, never repaying the existing people who make the sacrifice. It should be seen as a recurrent cost of growth, rather than investment.

Robinson (1974) developed Sauvy’s analysis of the opportunity cost of capacity expansion, illustrating the case of Bangladesh, which was at that time growing at 3 per cent per annum. He estimated that “the cost of standing still with present population growth represents just about 75 per cent of all the investment”. While planned levels of investment might increase per capita income by 30 per cent over the following 20 years, if a European level of population growth applied (0.45 per cent p.a. at that time) incomes would be increased by a factor of 2.5 (150%).

Expressing the required “demographic investment” as a per cent of GDP allows some assessment of the ability of a society to maintain such levels of sacrifice. It brings into stark relief the opportunity cost – what advantage may be gained if the funds invested in capacity expansion were released for other purposes. Estimates given in the literature for each one per cent population growth include 4 per cent for maintenance of housing and public infrastructure plus 3 to 4 per cent for the creation of employment (Sauvy, 1958; Robinson, 1974). Thurow (1986) estimated 12.5% of GDP per one per cent population growth. This range concurs with estimates of actual expenditure per one per cent population growth: O’Sullivan (2012) calculated 8.7 per cent for Australia, and the current study found 6.9 per cent for the UK.

Despite the early literature on the opportunity cost of capacity expansion, these costs are ignored in more recent discourse on population and development. The economic stimulus invariably seen in developing countries that have reduced their birth rate via family planning has usually been attributed to the “demographic dividend”. This is the change in age structure, with a shrinking proportion of the population represented by dependent children and an increasing proportion of working age. However, the demographic dividend presents only a narrow window of a few decades, before the increase in older people reduces the proportion of working age.

The ageing of developed countries has led to an anxiety among policy-makers, who assume that the workforce will shrink in proportion to the working age population. In fact, such a shrinkage has not yet been observed. The oldest nations to date, Japan and Germany, have the same proportion of the total population employed as the more youthful developed nations such as USA and Australia. With less pressure of unemployment to reduce wages, they also have among the lowest levels of income inequality.

Notwithstanding that the burden of old age dependency may be overstated, the idea that increasing population growth will substantially alleviate this burden is ill-founded. Among the ONS projections, variation of either migration rates or fertility rates has almost no impact on the proportion of working age people in the year 2100: the range is 57.0 to 58.1 per cent, compared with the present 61.9 per cent working age. The reduction is almost entirely due to the 13-year increase in longevity assumed in these projections – a change policy-makers are unlikely to try to avoid. A small increase in workforce participation would accommodate it, and the experience of Japan and Germany suggests that this will be an automatic response to reducing the oversupply of labour. For the dubious benefit of diluting the population of retirees, pronatalist and high immigration policies might double the population, not only costing trillions of pounds as outlined above, but increasing dependence on imported food and energy, both facing increasing costs and decreasing security of supply in the decades ahead.

The effect of reduced population growth rate releasing funds from capacity expansion might be called the "infrastructure dividend" – for the sake of a simple tag, lumping equipment and professional personnel under the umbrella of "infrastructure". The infrastructure dividend is almost certainly a greater economic stimulus than the demographic dividend. It is not dependent on the ability to train and gainfully employ the working age population, and it does not diminish as populations age. Even accepting the pessimistic models, where workforce shrinks in proportion to the working age population, the cost of population growth is far greater than the cost of the small extent of ageing it may offset (O'Sullivan, 2012).

Public or Private Costs?

The costs included in the above estimates include both public and private costs. It would be useful to know the extent to which population growth directly impacts on government budgets. However, the distribution of costs between public and private entities has shifted considerably over recent decades, as has the way in which people pay for them. The privatisation of utilities and railways is a major component of this shift. Public-private partnerships further blur the boundary. A school that would formerly have been built using tax revenue may be built by a private investor. The cost to government may have actually increased, but instead of appearing as capital expenditure, it appears as an ongoing service charge or rent.

As a result, it is difficult to disaggregate the costs of durable assets meaningfully between public and private funding sources. It is better to think of all durable assets, both public and private, contributing to the betterment of society. The introduction of university fees has substantially shifted the burden of professional training from public to private funds, although the graduating doctors and engineers contribute to societal quality of life in the same way as before.

The difference between a high-taxing nation with many nationalised services and a low-taxing nation with mostly private service providers may have implications for equity of access, which are worthy of analysis. However, this study, which focuses on the aggregate spending, does not address these issues.

A tale of two nations

It is often assumed that additional people more than pay for themselves, through their net contribution to the economy. However, a large number of studies have shown that population growth has a roughly neutral effect on GDP per capita, assuming capacity is expanded to provide jobs and maintain productivity of work for the added people. One per cent more people might be expected to generate one per cent more GDP and tax revenue. Given that these people also require one per cent more services of all kinds, their additional contribution clearly cannot cover 50 per cent more infrastructure, 35 per cent more training and 10-20 per cent more equipment.

However, this is a somewhat inaccurate perspective, since the costs are more accurately attributable to growth rate, not to any group of people who might be identified as "additional". It is the existing population who must pay for growth rate. It is immaterial whether they arrived yesterday or decades ago, through the airport or the maternity ward, or whether or not someone died or emigrated to make space for them. This burden of growth rate diverts income from other activities which could improve their quality of life, and hence represents an opportunity cost.

It is conceptually difficult to consider costs attributable to growth rate, rather than to a person. It may be better illustrated by comparing two hypothetical nations. At the moment we observe them, they have the same population and GDP, but one has a stable population and the other is growing at two per cent per annum.

The growing population will have twice as many construction sites and people employed in the building industry. It will likely endure productivity loss from the disruption of activities surrounding constructions, and crowding of roads and hospitals due to the usual lag between the need for new capacity and its delivery. All this activity is not delivering any additional service to the people already present, but merely catering for those yet to be added. Cost of living is elevated as governments and utilities recoup the cost of extra infrastructure through taxes and service charges. Around twice as many people will be establishing a household for the first time, taking on mortgages, generating demand for imports and cutting back on their expenditure on local goods and services. Increasing competition for real estate inflates the cost of housing and commercial rents, and the high demand for capital means high interest rates. Domestic saving capacity declines as the mortgage burden climbs, and the high proportion of mortgagees and lower proportion of older adults with net savings means domestic capital is in short supply. Consequently, development is increasingly funded by foreign debt or foreign direct investment, leading to increasing expatriation of profits and rents. Local spending power is consequently reduced, while the growing population needs ever more jobs. Yet the high cost of living damages international competitiveness in manufacturing. Unemployment climbs and wages are pushed as low as the inflated rents will allow. This further suppresses savings, increasing dependence on foreign investment and steadily reducing the proportion of national assets that actually belongs to the national population. Inheritance per capita is low and is increasingly unequally distributed as ownership of capital concentrates into fewer hands. Inequality of wealth and income expands, and with it levels of stress, depression, obesity, suicides and crime (Wilkinson and Pickett, 2009).

The stable nation has just as much income from exports but can spend more of it on things that improve quality of life. Its smaller construction industry would be balanced by more rapid adoption of new technologies, greater employment in entertainment and the arts, higher quality education and health care. Housing is not a large proportion of cost of living, since most people inherit some property and land values are stable, deterring speculators. This nation would, no doubt over time, have a higher proportion of retired people. But the national savings rate is ample to provide for them, since the demands on it for infrastructure are modest. With modest lifetime cost of housing, retirees have ample savings and their spending power and demand for services creates well-remunerated jobs. Thus the interest paid by mortgagees accumulates in pension funds and in turn generates local jobs, rather than draining out of the economy to foreign investors. There is no shortage of workers, only lower unemployment and higher workforce participation. Income inequality declines, reducing the burden of many social ills.

These anecdotes highlight impacts of population growth that go beyond the costs quantified in this paper, although they are in part a consequence of them. The most important overall trend is the shift of revenue from labour to capital, increasing inequality of wealth, and the increasing proportion of economic rents that are expatriated to foreign investors. The rising tide does not lift all boats, since capital's gain is directly at the expense of an even greater loss to labour. The importance of natural resources per capita, and the costs and vulnerability of a population which exceeds its nation's carrying capacity, are not considered in this discussion, although they are clearly of vital importance to the prospects of future generations.

In the real world, in a globalised economy, even a nation with a stable population is vulnerable to the oversupply of labour elsewhere, competing for market share with domestic production. Yet the dynamics described above can be seen, for instance by contrasting Australia and Germany.

The UK has had modest population growth up to the turn of the century. It has recently chosen a higher growth path. The analysis presented in this paper suggests that this decision should be reviewed.

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