Assessing long-run economic benefits attributed to an IVF-conceived singleton based on projected lifetime net tax contributions in the UK†

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BACKGROUND: Over the past decade, demand for fertility treatments has increased as a result of delaying time to first pregnancy and growing awareness and acceptance of available treatment options. Despite increasing demand, health authorities often view infertility as a low health priority and consequently limit access to treatments by rationing and limiting funds.

METHODS: To assess the long-term economic benefits attributed to in vitro fertilization (IVF)-conceived children, we developed a health investment model to evaluate whether state-funded IVF programmes in the UK represent sound fiscal policies. Based on the average investment cost to conceive an IVF singleton, we describe the present value of net taxes derived from gross taxes paid minus direct government transfers received (e.g. education, health, pension) over the lifetime of the child. To establish the present value of investing in IVF, we have discounted all costs from benefits (i.e. lifetime taxes paid) using UK Treasury department rates based on a singleton delivery with similar characteristics for education, earnings, health and life expectancy to a naturally conceived child.

RESULTS: The lifetime discounted value of net taxes from an IVF-conceived child with mother aged 35 is £109,939 compared with £122,127 for a naturally conceived child. The lifetime undiscounted net tax contribution for the IVF-conceived child and naturally conceived child are £603,000 and £616,000, respectively.

CONCLUSIONS: An investment of £12,931 to achieve an IVF singleton is actually worth 8.5-times this amount to the UK Treasury in discounted future tax revenue. The analysis underscores that costs to the health sector are actually investments when a broader government perspective is considered over a longer period of time.

Key words: health investment / in vitro fertilization (IVF) / generational accounting / economics / live birth

Introduction

Rising healthcare expenditure and demographic transition due to falling fertility rates and increasing life expectancy are two issues currently facing most industrialized countries. These two issues should not be seen in isolation as population ageing is expected to cause increases in healthcare expenditure, whereas falling birth rates in many countries will result in fewer young people entering the labour force in a generation’s time. A shrinking work force available to pay for state-funded health services and non-health government programmes in the future, and an increasing size of the population dependent on these services is posing significant economic challenges for these countries.

Concerns over increasing age-related public expenditure and ageing populations are not restricted to the health sector. In 1991, a new methodology referred to as generational accounting (GA) was developed to evaluate whether current governmental fiscal policies will disproportionately burden future generations (Kotlikoff, 1992). GA is used to evaluate the present value of lifetime net taxes—gross taxes minus direct financial transfer (health, education, pension, etc)—for population cohorts over many generations. In principal, GA considers whether there will be sufficient tax revenue collected in the future to pay for government programmes and whether tax increases or other policy adjustments are necessary to cover government expenditures in the future, and whether the tax burden is evenly distributed over generations or whether costs are simply passed onto future generations.

†An earlier version of the model and concept described here was previously presented at the ESHRE annual meeting in 2006 as Ledger et al. abstract (i74). M.C. is a former employee of Ferring Pharmaceuticals.
The main source of revenue for most governments is through taxation that can be influenced by the proportion of tax levied per individual and the size of the work force. Within the GA framework, demography plays a central role in these calculations because it defines the size of the working-age population available in the future to pay taxes. All things being equal, if benefits are to remain constant, a decreasing tax base implies that the contributions per individual need to increase. Conversely, an increasing tax base would suggest a smaller tax contribution per individual (Cardarelli et al., 2000).

In an effort to control healthcare costs, various demand and supply measures are being introduced and increasingly rationing is used as decision-makers and in some instances the public consider how best to allocate scarce healthcare resources (Redmayne and Klein, 1993; Gloucestershire, 2006). In several countries, the need to ration care has led health agencies to conclude that infertility is a low health priority and funding for fertility services has been reduced or withdrawn leaving many infertile couples without access to care (Dill, 2002; Gloucestershire, 2006). In Germany, recent in vitro fertilization (IVF) funding cuts resulted in a 50% reduction in the overall number of IVF cycles undertaken (Thaele and Uszkorkt, 2007). Increasingly, demographers have started to pay attention to the proportion of people that are willing but unable to have children and the extent to which assisted reproductive technologies (ART) can influence population structures (Hoorens et al., 2007; Jensen et al., 2008).

The past decade has witnessed increased demand for ART and which IVF is predominant. Increased demand is attributed to factors including increasing prevalence of infertility resulting from couples delaying time to first pregnancy, increasing obesity and an increased prevalence of sexually transmitted diseases, as well as an increased awareness of available infertility treatment options. In countries with generous funding for fertility treatments, for example Denmark, the proportion of infants born after either in vitro techniques or after intrauterine inseminations comprised 6.2% of all newborns during 2002 (Andersen et al., 2006). Given the importance of birth rates for achieving generational balance described earlier, it is possible to imagine how the benefits of ART may extend beyond the benefits conferred on the parents and offer a much broader benefit to society.

To investigate whether ART represents good use of public resources in the UK, we developed a health investment model to evaluate net taxes attributable to an IVF-conceived singleton in the future using the GA analytical framework. The model explores lifetime financial transactions between individuals and the state to derive the lifetime net tax contribution. As IVF is unique among all medical interventions in that its utilization leads to the creation of life, we believe that this approach is appropriate to account for benefits attributed to ART-conceived children which are likely to extend over many generations. We envisage that this research can provide a balanced economic viewpoint regarding the long-term benefits of ART and inform future policy in this area.

**Materials and Methods**

### Qualitative description of the model and its assumptions

After the GA framework described by Cardarelli et al., we model direct financial transactions between an IVF-conceived singleton and the UK government over their projected lifetime (Cardarelli, 2000). Based on a previously reported health investment model, the average IVF treatment costs to achieve a singleton live birth are treated as an investment in human capital with long-term economic consequences (Connolly et al., 2008). In this contract, the state makes age-dependent direct financial transfers to the individual and the individual pays money to the state through taxation. In the model, we assume the child conceived through IVF is a singleton with average education, earnings, health and life expectancy.

Broadly speaking, there are five stages of the model namely early childhood, primary education, secondary education, employment and retirement. During the first three stages of life, the individual is a net receiver; direct financial transfers from the state to the individual consist mostly of child benefits, child tax credits, education and healthcare. After the individual has entered the work force, the state will gradually become a net receiver based on the discounted net taxes. After the individual has retired, tax contributions reduce, but health and pension benefits will be provided until the end of life.

### Quantification of the net tax contributions

Applying the generational accounting framework, we can derive the net tax contribution or net tax deficit for an individual at any stage of life using the following equation:

$$ C(t) = T(t) - E(t) - H(t) - C(t) - P(t) $$

where $T(t)$ is the gross tax revenue paid to the state; $E(t)$ and $H(t)$ are the education and healthcare costs to the state, while $C(t)$ are the child tax credits; and the state pension is defined as $P(t)$. The individual also draws a private pension of which the state receives a percentage through taxation. The net tax contribution at any point in time is represented by $C(t)$. The model for each stage depends on the functional forms for income, proportional taxes, education costs and healthcare, as well as child tax credits. The direct costs at each stage are based on current averages and adjusted accordingly over the period defined as follows:

(i) childhood: from birth to year $t_C$;
(ii) primary education: from year $t_P$ to year $t_{C'}$;
(iii) secondary/higher education: from year $t_{C'}$ to year $t_{W'}$;
(iv) employment: from year $t_{W'}$ to year $t_T$;
(v) retirement: from $t_T$ until death, $t_D$.

In the health investment model, we assigned the following vales for each of the constants described above: $t_C = 6$, $t_P = 16$, $t_{W'} = 20$, $t_T = 68$, $t_D = 78$. Based on recent Pension Commission, recommendations we have set the age for retirement at age 68 (Turner, 2005).

### Labour productivity growth

To account for economic growth over time, wages and governments transfers are adjusted according to labour productivity growth (Auerbach et al., 1999; Cardarelli et al., 2000). In the model we have used, recent labour productivity growth estimates for the UK produced by the European Commission suggesting annual growth of 1.9% during the period 2004 to 2050 (Carone et al., 2006). These estimates are consistent with labour productivity estimates provided by the Organisation for Economic Cooperation and Development (OECD, 2008) that also indicate a slowdown in productivity in recent years.

### Government transfers

To derive average net tax contributions, we deduct direct financial transfers based on average 2005 contributions from gross tax contributions. In the model, we have allowed direct government financial transfers to grow according to labour productivity growth estimates.
Education

Education costs are based on children attending state-funded schools and are obtained from the Department for Children, Schools and Families (DCSF, 2008). The average annual cost per pupil in the base year was £4200.

Healthcare

Healthcare is one of the more difficult expenditure parameters to estimate and predictions for the future vary (Cutler and Sheiner, 2001; Reinhardt, 2003; Gray, 2005). In 2005, health spending in the UK accounted for 8.3% of gross domestic product of which 87% was funded through public sources (OECD, 2007). To reflect differences in healthcare consumption during life, we have used age-specific health expenditure (Mahal and Berman, 2001). The age-specific per capita expenditure was used in the model obtained from the UK Department of Health (Summerfield and Gill, 2005). In the model, we assume an annual 3% increase in age-adjusted health expenditure. This figure is below the average annual real growth in National Health Service (NHS) expenditure of 7.4% between 2002 and 2007; however, the 3% figure does reflect anticipated funding growth from 2022 onwards (Wanless et al., 2007). Similarly, generational accounts produced by Cardarelli et al. (2000) also reflect a slowdown in healthcare growth per beneficiary in the future. Alternative annual NHS expenditure increases of 4% and 5% are examined in the sensitivity analysis.

Child tax credits

The state allows for child tax credits up to the age of 16. The average child tax benefit per household reported in 2003–2004 was £500 which grew according to productivity growth (Jones, 2005).

Pension

In 2003–2004, the average retired person receives a pension comprised 51% state pension and 49% derived from private sources. The model assumes this to remain unchanged; however, pension reform will likely cause considerable shift towards private pensions in the future. In the analysis, private pensions are considered because of the tax revenue derived from this source of earnings. The annual state and private pensions in the base year and projected forward were £8139 and £7972/year, respectively (Balchin and Bullen, 2005).

Income

Average age stratified income was obtained from the 2002–2003 survey of personal income (SPI) from a representative sample of those liable to pay UK taxes (Inland Revenue, 2005). The data show that the average income varies as a function of age (Fig. 1): it first increases, peaks at around age 45 and then declines. This trend was fit statistically to a function $I_0$ (The function $I_0$ takes the form: $I_0 = A \cdot e^{-1/2(\text{AGE}-\mu)/\sigma} + B \cdot \text{AGE}$, where $A = 26.633$, $B = 180$, $\sigma = 16$, $\mu = 43.5$) (Fig. 1). The average income $I$ is assumed to increase with the rate of productivity increases over the duration of the model in which the governing equation can be expressed as:

$$\frac{dI}{dt} = \alpha I \iff I = I_0 e^{\alpha \delta t}$$

Where $I_0$ is the average and age-dependent income at $t = 0$, in the model assumed to be 2005. Fig. 1 presents the observed mean SPI and the projected income data adjusted for growth over the lifetime of the individual.

Figure 1 Mean age-stratified income from the Survey of Personal Income data (HM Revenue and Customs) and projected aged-stratified lifetime income adjusted according to work productivity increases over lifetime of the individual.

Tax contributions

Taxation is the main source of income for government, hence it is the most relevant parameter for projecting future revenue. Tax rates applied in the model are derived from estimates collected from the Expenditure and Food Survey which is an annual survey of income and expenditure of private households in the UK. The average household tax applied in the model was 35% which includes income tax, council tax, value added taxes and duties (Lakin, 2004; Jones, 2005). As reported by Jones, the income tax component makes up 17% of the tax liability and this was confirmed using Her Majesty’s (HM) Revenue and Customs Income tax statistics and distributions data (Jones, 2005). The percentage tax liability on retired households in 2003–2004 represents 30% of gross income (Jones, 2005). In the model, we assume no change to the percentage tax contribution over time which may be an idealized assumption when compared with future UK projections (Weale, 2006).

Discount rate

To reflect the depreciation of money over time, we applied a discount rate on the costs of IVF to reflect the future value of costs and benefits in present value (2005). This calculation method is also referred to as net present value. As stated in the HM Treasury Green Book Appraisal and Evaluation in Central Government, valuing future costs and benefits in discounted terms is the primary criteria for establishing whether government action on programmes can be justified (HM Treasury, 2003). We applied a 3.5% discount rate to all costs and benefits as recommended by HM Treasury for evaluating social costs and benefits of new policies and programmes in the UK (HM Treasury, 2003). The discount rate is compounded continuously over time. Furthermore, because of the uncertainty associated with cash flows in the future described in the model, we have evaluated discount rates of 4.5% and 5.5% in the sensitivity analysis.

IVF costs

The incremental investment costs to the UK NHS required to conceive an additional live birth from IVF were obtained from estimates published by the National Institute for Health and Clinical Excellence (NICE, 2004). The NICE guidelines highlight variations in IVF success by age of the woman treated to derive an age-specific cost per live birth as follows:
aged 24, £11,917; aged 35, £12,931; aged 39, £20,056. The present value of net taxes was derived for the three different costs per live birth described by NICE. Delivery costs of £3313 for both the naturally conceived and IVF-conceived singleton have been included in the model (Ledger et al., 2006).

**Results**

The projected lifetime net taxes are illustrated in Fig. 2, where the varying discounted tax position between the individual and the state is seen to change over time. A positive value at any given point in time indicates the return on investment from IVF expenditure for the state. The trace in Fig. 2 indicates that in the early years of life, the net balance for the state is negative as the state provides education, health and family allowances. As the individual enters their working years the balance shifts in favour of the state from tax payments and reduced expenditure directed to the individual. The net tax position for an IVF- and a naturally conceived child follow a similar trace where the only difference between the two is the additional IVF investment cost required for conception. We also provide estimates which extend beyond normal UK life expectancy where the financial position between the individual and the state can start to approach a negative balance.

The lifetime present value of net taxes based on projected life expectancy for a naturally and IVF-conceived child in 2005 is provided in Table I. The present value of future taxes from an IVF-conceived child from a mother aged 24 is £110,210. Variations in the cost per live birth for a mother aged 35 and 39 result in a discounted net tax contribution of £109,939 and £101,871, respectively. The break-even age, defined as the point at which the financial position between the individual and the state, for a naturally conceived child crosses unity at age 36. The break-even age for the IVF-conceived child is between 38 and 39 years of age dependent on the age of the mother at birth (Table I). This can also be seen as the age at which the IVF-conceived child has paid for their own IVF costs in addition to all their other previous government transfers.

The undiscounted lifetime net tax contributions for IVF and naturally conceived children are also provided in Table I. These figures represent the lifetime balance sheet based on gross taxes paid and deducting age-specific government transfers without applying a discount rate. The undiscounted net tax contribution for a naturally conceived child is £616,135 and ranges from £596,000 to £604,000 for IVF-conceived children depending on the age of mother at conception.

**Sensitivity analysis**

A parametric study was carried out to assess the influence of changes to baseline parameters on discounted future net tax contributions. The model is mostly sensitive to those parameters that are applied over the lifetime of the model such as labour productivity growth, percentage increase in healthcare expenditure and the discount rate which influences the discounted future tax revenue. We tested six different scenarios in the sensitivity analysis by varying the discount rate up to 5.5% and annual healthcare expenditure to 5% as well as changes in ±0.5% differences in labour productivity growth (Table II). Under the scenarios examined in the sensitivity analysis, we observed that investing in IVF continues to generate a positive return on investment for the state as do naturally conceived children, although the former returns are slightly lower because of IVF investment costs. Radical variations in the sensitivity analysis are not viable because competing government policy interventions would be introduced to counterbalance prevailing economic conditions.

**Discussion**

The most striking observation from our research is that what appears as a cost in the balance sheet of the health service is actually an investment with future returns when a broader government perspective is considered over a longer-time horizon. Based on the average NHS cost of £12,931 to conceive one IVF child and current levels of direct financial transfers from the UK government, the discounted return to the state is ~£109,000 over the child’s projected lifetime. Based on the

<table>
<thead>
<tr>
<th>Table I</th>
<th>Lifetime discounted and undiscounted net taxes based on life expectancy for naturally conceived child and IVF-conceived children in the UK with variations in the cost per live birth based on age of mother</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of conception and costs per live birth</td>
<td>Breakeven point (age)</td>
</tr>
<tr>
<td>Naturally conceived child (cost = minimal)</td>
<td>36</td>
</tr>
<tr>
<td>IVF child conceived from mother aged 24 (cost = £11,917)</td>
<td>38</td>
</tr>
<tr>
<td>IVF child conceived from mother aged 35 (cost = £12,931)</td>
<td>38</td>
</tr>
<tr>
<td>IVF child conceived from mother aged 39 (cost = £20,056)</td>
<td>39</td>
</tr>
</tbody>
</table>
Table II Discounted net tax contributions for an IVF and naturally conceived child in the UK based on changes in parameters (from discount rate 3.5%, healthcare growth 4% and labour productivity 1.9%) and based on mother aged 35

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Lifetime net tax contribution IVF-conceived child</th>
<th>Lifetime net tax contribution naturally conceived child</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount rate 4.5%</td>
<td>£57 352</td>
<td>£70 283</td>
</tr>
<tr>
<td>Discount rate 5.5%</td>
<td>£23 198</td>
<td>£36 130</td>
</tr>
<tr>
<td>Healthcare growth 4%</td>
<td>£88 300</td>
<td>£101 230</td>
</tr>
<tr>
<td>Healthcare growth 5%</td>
<td>£47 183</td>
<td>£60 114</td>
</tr>
<tr>
<td>Labour productivity 1.4%</td>
<td>£73 670</td>
<td>£86 601</td>
</tr>
<tr>
<td>Labour productivity 2.4%</td>
<td>£155 185</td>
<td>£168 116</td>
</tr>
</tbody>
</table>

In the analysis described here, we have modelled the consequences of a singleton delivery with average health and life expectancy characteristics which some would disagree. Available evidence does suggest that costs to the health service for twins and triplets can increase by 3- and 10-fold, respectively (Ledger et al., 2006). These additional costs were explored in our analysis and while the financial penalties for multiple embryo transfer are high, the discounted net tax return to the state remained positive, suggesting the additional costs do not substantially influence our conclusions. Furthermore, the conclusions presented here do not account for spontaneous pregnancy rates which may over estimate success rate of the technology leading to a higher cost per live birth. However, based on current and historical waiting lists for treatment in the UK, the NICE figures may already account for spontaneous pregnancy rates. Based on the assumptions applied here, the results should be considered as a first order approximation.

In 1972, Grossmann (1972) introduced the concept of ‘demand for health’ which describes the medical seeking behaviour of individuals which can influence health capital and ultimately human capital. In our analysis, we considered the ‘supply of health’ from the perspective of national health providers and whether there is a financial return for the state in the future from investing in medical technologies. Our analysis suggests that a state subsidy to cover the costs of ART represents a positive financial investment for the state. The results from the model have demonstrated that if the state were to invest in IVF, it could expect a return of ~£109 000 at the discounted present value and £603 000 undiscounted. These results do not suggest the state is profiting, rather the amount collected in lifetime tax contributions is greater than the direct transfers to individuals which allows for distribution of funds to meet other government obligations. The present model excludes public investment in, for example, infrastructure and defence. In other words, each child born through ART would contribute around £109 000 (discounted) towards the public spending budget over the course of their lifetime.

The methodology for assigning value derived from health investments applied in our model differs from previous health investment models. The most common approach for assigning value associated with health investments is based on the value of statistical life concept (Cutler and McClellan, 2001; Luce et al., 2006). The statistical life approach is commonly used in public policy evaluations to derive average investment costs required to prevent one death (Johansson, 2001). As the purpose of our analysis was to evaluate whether public subsidy of IVF represents good use of public resources, we applied a narrower government approach where the return on investment was based on future net tax contributions. Had we adopted a statistical life approach in our analysis, then an IVF-conceived child with average life expectancy would no doubt represent one of the most attractive health investments available.

As previously described we applied a narrow focus in our analysis which may suggest we have neglected a broader range of benefits that accrue to society and families from IVF treatment. In our model, we ignore benefits that accrue to couples achieving successful IVF treatment, as well as benefits to those couples failing IVF, which include the benefits of closure and peace of mind having had the opportunity to attempt all reasonable approaches to conception. The narrow government approach applied in our model also ignores the net marginal contribution of an individual to the economy and society other than as a source for future government revenues.

Role of health investment model in decision-making

The results presented here may have implications for shaping IVF policy in the future. In countries with birth rates below replacement level, one interpretation may be that funding IVF represents a good use of public resources with likely economic rewards in the future. In fact such conclusions have recently been taken in Korea and Sweden where increased public funding was made available because of low birth rates in these countries. Though the model and results presented here are applicable only to the UK, the methodology described here outlines an analytical approach for addressing the IVF access problem that exists in many countries.

The health investment model described here follows the GA framework used to inform public policy with respect to potential fiscal imbalances between generations (Kotlikoff, 1992). Although GA has been embraced by most OECD countries, the European Union and
World Bank for evaluating fiscal promises, there are a number of challenges in applying it to evaluate the adoption of medical technologies. In reality, healthcare resource allocation decisions are more often based on disease burden and other elements such as fairness and equity. Applying our approach to health funding may inappropriately suggest that health technologies are funded solely on the basis of tax revenues derived from individuals in the future based on expected increases in health and human capital. Under these circumstances, the methodology would obviously predicate against provision of costly healthcare to those who have retired from work. We do not advocate that this method should replace existing criteria for evaluating technologies, rather that the method can be used to augment existing methodologies. In some instances, the approach described here can be used to develop long-term fiscal benefits that can be derived from health investments, as is often the case with funding for IVF.

Conclusions
We have described a health investment model which estimates discounted future net tax returns to the UK government based on the average investment cost in IVF to achieve a singleton live birth. The analysis described here has focused narrowly on costs and benefits to a wider audience outside of the health sector. The results indicate that based on an investment of £12,931, the return on investment for the state over the lifetime of the child is 8.5-fold. The analysis described here has focused narrowly on costs and benefits in the form of future taxes to the UK government over the lifetime of the child and has not considered broader economic aspects that individuals can have on the economy which suggests we have underestimated the true economic impact of investing in IVF. Furthermore, because we have focused narrowly on economics and future tax contributions, our research fails to account for the effects of increased morbidity that may be applicable to some IVF-conceived children. We recognize there are challenges to applying this methodology in mainstream healthcare decision-making; however, the approach used in our analysis can be a powerful tool to express future benefits attributed to investing in IVF to a wider audience outside of the health sector.

Author contributions
M.C., model concept and design, model development, model output, drafting original and revised manuscript.
F.G., model development, model output, drafting original and revised manuscript.
S.H., model development, model inputs, drafting original and revised manuscript.
W.L., medical and model inputs, drafting original and revised manuscript.

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