The role of foreign capital flows in health finance

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Abstract

Few long run trends have transformed developed economies more than the concurrent rise in longevity and health spending. This study utilizes a novel open economy version of the Dalgaard and Strulik (2014) health deficit model, calibrated to match UK aggregates. Several inferences are drawn from the model. First, a portion of the decline in the UK's current account can be attributed to rising health demand. Second, the closed economy version of the model understates the welfare gains from income growth and medical innovation. Finally, financing new health care expenditures via deficit spending is preferable to a balanced budget approach.

Keywords Open Economy; Capital Flow; Health; Health Finance; National Health Service
JEL Classification Number: D91, E13, F41, I13, I18

1 Introduction

Health care expenditures among advanced economies have been outpacing GDP growth for several decades. Numerous studies have concluded that this phenomenon is largely driven by the optimal response of households to medical innovation, rising income levels, and increased generosity of health insurance.[1] However, as this trend persists, the burden of financing health care will intensify. Accommodating these additional expenditures requires some combination of tax increases, cuts to discretionary government spending, increased budget deficits, increased out-of-pocket shares, or increased insurance premiums. These measures impact the economy to differing degrees and are often unpopular with voters, even when voters are generally dissatisfied with the level of care they receive.[2] Aside from the fiscal consequences of health spending, health itself impacts the economy more generally, contributing to aggregate welfare, impacting longevity and time preferences, and influencing productivity.

Consequently, finding the optimal mix of health care provision and financing has become one of the principal challenges policymakers currently confront. While this view is frequently acknowledged, relatively few macroeconomic studies have attempted to identify the optimal role of the government in health finance.[3] Utilizing a novel variant of the Dalgaard and Strulik (2014) health deficit life-cycle model, this study examines the aggregate consequences of rising health demand in an open economy context. To date, this is the first macroeconomic health study to consider the interplay between health behavior and international finance.

As the conspicuous absence of open economy models in the macro-health literature reveals, the connection between health and international finance is not immediately evident. However, as I will show, the introduction of open economy assumptions impacts the behavior of agents in the model and alters the welfare implications of the model. In particular, the

[1]See Newhouse (1992) and Chernew and Newhouse (2011) for an excellent review of the early literature. More recent examples include Hall and Jones (2007), Chandra and Skinner (2012), Fonseca et. al. (2020), Frankovic et. al. (2020), Böhm, Grossman, and Strulik (2021), Chen et. al. (2021), and Frankovic and Kuhn (2023).

[2]For example, the 2023 British Social Attitudes survey found that only 24% of respondents were either "very" or "quite" satisfied with the NHS, the lowest satisfaction level since the survey began in 1983. Additionally, 84% of respondents reported that the NHS faced either "major" or "severe" funding problems. Yet, when asked about how the government should address these problems, only 48% of respondents said the NHS should increase taxes and spend more, while another 48% said the NHS should either keep taxes and spending at current levels or reduce both.

[3]Atolia, Papageorgiou, and Turnovsky (2021), Chen et. al. (2021), and Kelly and Kuhn (2022) are notable recent examples of macro-level analysis of optimal health spending and government provision and finance of health.

experiments conducted in this study indicate that deficit spending is preferable to a balanced budget approach, but only under open economy assumptions where the government and the public have access to foreign asset markets. By utilizing foreign capital, the economy is able to devote a greater portion of GDP on health care without having to increase taxes or sacrifice non-medical consumption, investment, or discretionary government purchases.

At the same time, changes in health demand likely influence capital flows. Rising health expenditure shares are putting increasing strain on government budgets and have contributed to growing government budget deficits. According to the twin deficit hypothesis, an increase to a nation's government deficit will have an adverse effect on its current account. Health spending may also influence capital flows through its effect on a nation's demographics. Broadly speaking, the literature has found evidence that population aging impacts foreign trade and capital flows by changing the composition of consumption and household savings (Brooks, 2003, Backus, Cooley, and Henriksen, 2014, and Papetti, 2021), reducing the solvency of public pension systems (Börsch-Supan, Ludwig, and Winter, 2006, Attanasio, Kitao, and Violante, 2007, and Krueger and Ludwig, 2007), and contributing to secular stagnation (e.g. Hansen, 1939, Ferrero 2010, Dao and Jones, 2018, Eggertsson, Mehrotra, and Robbins, 2019, and Bárány, Coeurdacier, and Guibaud, 2023). The theoretical experiments contained in this study support the hypothesis that an increase to the health expenditure share diminishes the trade balance and increases foreign capital inflows.

The rest of the paper is laid out as follows. In Section 2, I construct and describe the model. As was briefly mentioned above, the model is a novel version of the health deficit model first introduced by Dalgaard and Strulik (2014). In particular, I modify Dalgaard and Strulik's model by incorporating an open economy general equilibrium framework. Then, in Section 3, I calibrate the model to match aggregates from the United Kingdom for two separate time periods, 1995-2004 and 2010-2019. Section 4 conducts experiments that simulate a rise in health demand following either a medical innovation or rising income levels. To demonstrate how the open economy assumptions influence the model, I conduct the experiments on the benchmark open economy model and an alternative closed economy version of the model. Finally, Section 5 provides concluding remarks.

2 Model

The economy is comprised of a continuum of distinct cohorts of individuals. For simplicity, it is assumed that individuals within each cohort are identical and that all individuals are identical at birth, irrestpective of which cohort they belong to. Cross-cohort heterogeneity exists due to the biological aging process and the lifecycle allocation of wealth and expenditures.

Following Dalgaard and Strulik (2014), the aging process is modeled as the progressive decline in bodily function that results from the accumulation of so-called health deficits. Conceptually health deficits are either acute and chronic medical conditions that diminish the individual's health and inhibit bodily function. As deficits accumulate bodily function declines and will eventually reach a minimum survivable threshold, where the individual will expire. Let $d(z)$ be the total stock of deficits the agent has accrued by age z. Deficits evolve throughout the agent's lifetime according to the following accumulation funciton

$$\dot{d}(z) = \mu(d(z) + a - Qh(z)^{\gamma}). \tag{1}$$

In equation (1), μ is the natural rate of deficit accumulation and a represents any exogenous factors that influence the rate of deficit accumulation. These exogenous environmental factors, such as pollution, the prevalence of infectious diseases, or public health measures within society may either enhance or inhibit the deficit accumulation, so a may be either positive or negative. Each individual in the model can purchase health care goods and services to mitigate the effects of health deficits. Let $h(z)$ be the quantity of health care goods and services purchased by an aged z representative agent. These health care investments are subject to diminishing returns, the rate of which is governed by the parameter γ. The current level of medical technology is captured by the term Q.

For the agent's optimization problem, the age of a new entrant to the economy is set at zero (i.e. $z = 0$). Each individual receives utility from consumption of non-medical goods and services (i.e. $c(z)$) and disutility from supplying labor (i.e. $l(z)$). Following Dalgaard and Strulik (2017), the intertemporal utility function of a new entrant is

$$V(0) = \int_0^{\hat{Z}} e^{-\rho z}[u(c(z)) - \theta l(z)]dz \tag{2}$$

where $\hat{Z}$ is the agent's endogenous terminal age, ρ is the rate of time preference, and θ is the disutility the agent receives from working. The instantaneous utility from non-medical consumption is

$$u(c(z)) = \begin{cases} \dfrac{c(z)^{1-1/\epsilon}}{1-1/\epsilon} & \text{if } 0 \leq \epsilon < \infty,\ \epsilon \neq 1 \\ \log(c(z)) & \text{if } \epsilon = 1 \end{cases} \tag{3}$$

where ϵ is the intertemporal elasticity of substitution for consumption.

Agents can accumulate wealth by either financing domestic investment in physical capital, or through purchase of foreign bonds. Let $k(z)$ be the stock of domestic capital owned by the agent and let $f(z)$ be the stock of foreign bonds held by the agent. Foreign bonds pay the world interest rate r, while domestic lending pays the domestic interest rate, r_k. Income earned from domestic capital is subject to a capital tax, which is assessed at the rate τ_k. Physical capital is assumed to depreciate at the constant rate δ.

Working agents are paid a fixed wage rate w, which is taxed at the rate τ_l. As was noted previously, agents consume medical and non-medical goods and services, $c(z)$ and $h(z)$ respectively. Non-medical consumption is taxed at the rate τ_c, while medical consumption is exempt from taxation. For simplicity, I treat the NHS's provision of health care services as a subsidy. The government's share of medical expenditures is σ_g, while the agent's out-of-pocket share is $\sigma_o = 1 - \sigma_g$. The flow budget constraint for the representative agent is

$$\dot{k}(z) + \dot{f}(z) = rf(z) + (1-\tau_k)r_k k(z) + (1-\tau_l)wl(z) - (1+\tau_c)c(z) - \sigma_o h(z) - \delta k(z). \quad (4)$$

To simplify things, it is assumed that agents enter the economy with no wealth (i.e. $k(0) = f(0) = 0$). Further, there is no bequest motive, so they will also die with no wealth (i.e. $k(\hat{Z}) = f(\hat{Z}) = 0$).

Each individual optimally chooses $c(z)$, $h(z)$, $l(z)$, $k(z)$, $f(z)$, and $d(z)$ to maximize (2), subject to (1) and (4). The optimal choice of non-medical consumption is described by the following first-order condition

$$c(z)^{-1/\epsilon} = \lambda(z)(1+\tau_c). \quad (5)$$

The left hand side of (5) is the marginal utility of consumption, which is equated to $\lambda(z)$, the Lagrange multiplier on financial wealth, weighted by the after-tax cost of consumption.

Optimal health care consumption requires setting the marginal benefits of medical consumption equal to the shadow cost of health care. The marginal benefit of health care is equal to the marginal product of health care investment (in terms of reduced deficit accumulation), weighted by the natural force of aging, μ, and the Lagrange multiplier on health deficits, $\psi(z)$. The shadow cost of health care is equal to the product of $\lambda(z)$ and the agent's out-of-pocket share σ_o.

$$-\psi(z)\mu\gamma Q h(z)^{\gamma-1} = \lambda(z)\sigma_o \quad (6)$$

The agent will choose to work as long as the marginal benefit of labor exceeds the disutility from labor, θ. The marginal benefit of labor is defined as the after-tax real wage rate, weighted by $\lambda(z)$

$$\lambda(z)(1-\tau_l)w \geq \theta.$$

The optimal retirement age is obtained by solving for the age $z = R$ where the marginal benefit of labor is equal to the disutility of labor. After substituting for $\lambda(z)$ using (5), the equation for determining the optimal retirement age is

$$\left(\frac{1-\tau_l}{1+\tau_c}\right)\frac{w}{c(R)^{1/\epsilon}} = \theta. \tag{7}$$

Optimizing over $k(z)$ satisfies the following first-order condition

$$(1-\tau_k)r_k - \delta = \rho - \frac{\dot{\lambda}(z)}{\lambda(z)}, \tag{8}$$

while the optimal allocation of wealth held as foreign bonds is determined according to the following condition

$$r = \rho - \frac{\dot{\lambda}(z)}{\lambda(z)}. \tag{9}$$

The optimal stock of health deficits is determined according to the following condition

$$\mu = \rho - \frac{\dot{\psi}(z)}{\psi(z)}. \tag{10}$$

The lifetime paths of $c(z)$ and $h(z)$ are derived from the first-order conditions above. The dynamic path of non-medical consumption is solved for by first differentiating equation (5) with respect to z and then substituting for the rate of capital gains (i.e. $-\dot{\lambda}(z)/\lambda(z)$) using either equation (8), or equation (9). This yields the following constant growth rate, g_c, for $c(z)$ throughout the agent's lifetime

$$\frac{\dot{c}(z)}{c(z)} \equiv g_c = \epsilon[(1-\tau_k)r_k - (\delta+\rho)] = \epsilon(r-\rho). \tag{11}$$

Note that this is the canonical Euler equation for consumption, with the g_c equaling difference between the return to capital and the rate of time preference, weighted by the intertemporal elasticity of substitution.

Lifetime health care expenditures will likewise grow at a constant rate, which I denote as g_h. This growth rate is obtained by differentiating equation (6) with respect to z, and substituting for the dynamic equations for the two Lagrange multipliers using equations (8) through (10).

$$\frac{\dot{h}(z)}{h(z)} \equiv g_h = \frac{(1-\tau_k)r_k - (\delta+\mu)}{1-\gamma} = \frac{r-\mu}{1-\gamma} \tag{12}$$

This Euler equation states that the lifetime growth rate of health care spending is positively affected with the return to savings and γ, the degree of diminishing returns to individual health care investments, and negatively affected by the natural rate of aging, μ. Assuming that $r > \mu$, health care expenditures will grow throughout the agent's life. Intuitively, this is occurring because the return to savings exceeds the rate at which deficits naturally accumulate. Therefore, young, healthy agents are better off deferring health investment and using this savings for health investment later in life.

Similarly, the positive relationship between g_h and γ suggests that for higher values of γ (i.e. γ near one), rational agents will defer health investment until later in life to a greater degree than they would for lower values of γ (i.e. γ closer to zero). Put differently, as $\gamma \to 1$, the rate at which diminishing returns to health investment sets in is relatively low. Consequently, the negative consequences of deferring health care investment until later in life are significantly lessened by the fact that consuming large quantities of health care does not significantly diminish the marginal benefit derived from consuming health care.

Solving the agent's problem requires solving for $c(0)$, $h(0)$, R, and $\hat{Z}$.[4] These three variables are solved for using the intertemporal budget constraint, the lifetime path of deficits, and setting the Hamiltonian function equal to zero at the terminal age $\hat{Z}$. The intertemporal budget constraint is obtained by integrating equation (4) forward from age zero until the terminal age $\hat{Z}$, which yields

$$(1-\tau_l)\int_0^R we^{-r_k z}dz = (1+\tau_c)\int_0^{\hat{Z}} c(z)e^{r_k z}dz + \sigma_o\int_0^{\hat{Z}} h(z)e^{-r_k z}dz \tag{13}$$

Likewise, the lifetime path of health deficits is obtained by integrating equation (1) forward, resulting in the following equation

$$\bar{d}e^{-\mu\hat{Z}} = d(0) + \mu a\int_0^{\hat{Z}} e^{-\mu z}dz - \mu Q h(0)^{\gamma}\int_0^{\hat{Z}} e^{(\gamma g_h - \mu)z}dz. \tag{14}$$

[4]Note that since g_c and g_h are constants, non-medical consumption and health care spending at any arbitrary age z will be a function $c(0)$ and $h(0)$, respectively.

Finally, at the terminal age, the Hamiltonian function will equal zero. We use this fact to complete the individual's problem. The terminal Hamiltonian is

$$u(c(\hat{Z}))c(\hat{Z})^{1/\epsilon} - \frac{\sigma_o}{1+\tau_c}\left[\frac{\bar{d}+a}{\gamma Q h(\hat{Z})^{\gamma-1}} - \frac{h(\hat{Z})}{\gamma}\right] - \frac{c(\hat{Z})+\sigma_o h(\hat{Z})}{1+\tau_c} = 0. \tag{15}$$

2.1 Aggregation

Aggregate production is characterized by a standard CES production technology

$$Y = \left[\alpha\left(A_K K\right)^{\frac{\xi-1}{\xi}} + (1-\alpha)\left(A_L L\right)^{\frac{\xi-1}{\xi}}\right]^{\frac{\xi}{\xi-1}} \tag{16}$$

In equation (16) above, A_L is the labor-augmenting technology parameter, A_K is the capital-augmenting technology, α is the output elasticity with respect to capital, ξ is the elasticity of substitution between capital and labor, K is the aggregate physical capital stock, and L is total employment. Both input markets and the market for final goods are assumed to be competitive, implying that the real wage rate is equal to the marginal product of labor

$$w = \frac{\partial Y}{\partial L}, \tag{17}$$

while r_k, the domestic real rate of return on capital is equal to the marginal product of capital

$$r_k = \frac{\partial Y}{\partial K}. \tag{18}$$

The aggregate capital stock evolves according to a standard capital accumulation function

$$\dot{K} = I - \delta K, \tag{19}$$

where I is aggregate domestic investment. The aggregate wealth accumulation function is derived from aggregating over the agents' flow budget constraints, yielding the following aggregate resource constraint:

$$\dot{K} + \dot{F} = rF + Y - C - \sigma_o H - \tau_k r_k K - \tau_l w L - \tau_c C - \delta K. \tag{20}$$

In equation (20), F represents the aggregate stock of foreign assets, Y is real GDP, C is aggregate consumption of non-medical goods and services, and H is aggregate health care consumption. Note that the assumption that agents are identical when they enter the economy implies that $c(0)$, $h(0)$, g_c, g_h, R, and $\hat{Z}$ will be identical for every individual in the economy. Given this and normalizing the population of each cohort to one, aggregate consumption, health care expenditures, and employment are defined as

$$C = c(0)\int_0^{\hat{Z}} e^{g_c z} dz, \quad H = h(0)\int_0^{\hat{Z}} e^{g_h z} dz, \quad L = \int_0^{\hat{Z}} l(z) dz = R. \tag{21}$$

The government finances its expenditures on health care and government purchases by collecting taxes and issuing bonds. Referencing the previous discussion of the government's role in providing health care, σ_g represents the government's share of aggregate health care spending. Thus, total government spending on health care is $\sigma_g H$. Letting D and G represent the total stock of government debt and aggregate government purchases, respectively, the government's budget constraint is

$$\dot{D} = rD + G + \sigma_g H - \tau_k r_k K - \tau_l w L - \tau_c C. \tag{22}$$

Note that the government has the ability to borrow from either domestic or foreign sources. Therefore, government issued bonds will pay the world interest rate, r.

Combining the aggregate resource constraint from (20) with the government's budget constraint from (22) reduces equation (20) to

$$\dot{K} + \dot{F} - \dot{D} = r(F - D) + Y - (C + H + G + \delta K). \tag{23}$$

By definition net exports (i.e. N) is equal to the gap between real GDP and aggregate domestic expenditures

$$N = Y - (C + H + I + G). \tag{24}$$

The nation's current account is derived by substituting for $\dot{K}$ in (23) using equation (19) and rearranging terms, yielding

$$\dot{T} = rT + N \tag{25}$$

where $T = F - D$ and rT is primary income.

Finally, to evaluate the aggregate welfare implications, I utilize two different measures of welfare. The first is the intertemporal utility function defined in equation (2), which will act as the primary measure for individual level welfare. The second measure is steady state aggregate welfare, denoted by Ω, which is defined as the aggregate sum of each agent's instantaneous utility

$$\Omega = \int_0^{\hat{Z}} [u(c(z)) - \theta l(z)]dz. \tag{26}$$

3 Calibration

Due to the complexity of the model, an analytical solution of the model is intractable. Therefore, in lieu of an analytical solution, I conduct a numerical analysis of the calibrated model. The calibration of the model occurs in two stages. First, I calibrate the model to match aggregate UK data for the period 1995-2004. Then, treating ρ, ϵ, θ, γ, μ, $d(0)$, $\bar{d}$, α, ξ, and δ as fixed parameters, I adjust the remaining parameters to recalibrate the model to match UK aggregates from 2010-2019.[5] This two step calibration exercise demonstrates the ability of the model to replicate the UK economy across different time periods. Additionally, this process helps ensure that the flexible parameters are not chosen in an ad hoc manner, but are selected to accurately reflect the changes that occurred in the UK economy between the two periods.

The data for GDP, its components (including health care expenditure data), and the total population was obtained from the Organization for Economic Cooperation and Development (OECD). Additionally, the public health care expenditure share σ_g is estimated using OECD health expenditure data. The individual tax rates on capital, labor, and consumption are taken from McDaniel (2007). Data for the retirement age R and the terminal age $\hat{Z}$ are taken from the UK Office for National Statistics (ONS). Since it is assumed that new agents enter the economy at age 20, the terminal age is equivalent to the average life expectancy at age 20, which I obtained from the ONS National Life Tables. Since ONS does not provide a single estimate for average years in retirement, but rather divides its estimates by sex, I construct a national average age at retirement. Using data the National Life Tables, I estimate the average age at retirement in two steps. First, I subtract the average years in retirement from the life expectancy at age 20 to get the average age at retirement for each sex. Then, I take the weighted average of these two ages using the estimated number of survivors of each sex from the National Life Tables.

Table 1 details the parameterization of the benchmark specification. The preference parameters are chosen for model fit and are consistent with literature standards. The rate of time preference, ρ, is set at 0.045. Following Dalgaard and Strulik (2014 & 2017), I assume log utility for consumption, implying that $\epsilon = 1$. The disutility from labor (θ) is

[5]Note that the flexible parameters will therefore be Q, a, A_L, A_K, r, g, σ_g, τ_k, τ_l, and τ_c.

set at 0.8 to equate the endogenous retirement age, R, to the average retirement age in the data. Many of the model's parameters, particularly those relating to health deficits, are borrowed from Dalgaard and Strulik (2014 & 2017). Relying on data from Mitnitski et. al. (2002), Dalgaard and Strulik (2014) estimate that the natural rate of deficit accumulation μ is around 0.043. They also rely on Mitnitski et. al. (2002) for determining the initial (i.e. age 20) and terminal deficit stocks, setting $d(0) = 0.0274$ and $d(\hat{Z}) = 0.1005$. Finally, they set $\gamma = 0.2$ to calibrate g_h to match average lifecycle growth rate of health care spending. The capital share and depreciation rate are based on literature standards (i.e. $\alpha = 0.3$ and $\delta = 0.05$).

Chosing a value for the elasticity of substitution between capital and labor (EOS) (ξ in the current model) is challenging given the lack of consensus within the literature. On one end of the spectrum, there are many studies that conclude that the EOS is less than one. For example, a recent meta-analysis of 77 studies by Knoblach, Roessler, and Zwerschke (2020) concluded that the long-run meta-elasticity for the US economy falls in the range of 0.45-0.87. Similarly, Mallick (2012) conducted a cross-country analysis of 90 countries and found that the average EOS within the OECD is 0.34. More importantly for the current study, Mallick (2012) estimates an EOS of 0.195 for the UK. Nevertheless, there are several well-known and highly cited studies that also utilize cross-country data to estimate ξ, such as Duffy and Papageorgiou (2000), Masanjala and Papageorgiou (2004), Karabarbounis and Neiman (2014), and Piketty (2014), that find evidence that the EOS may be well in excess of one. Therefore, I have chosen a moderate value for the EOS (i.e. $\xi = 0.5$).

Table 1: Fixed Parameters (Calibration)

Description	Notation	Value
Rate of time preference	ρ	0.045
Intertemporal elasticity of substitution	ϵ	1
Disutility from labor	θ	0.8
Health investment elasticity of health care	γ	0.2
Natural rate of aging	μ	0.043
Health deficits at age 20	$d(0)$	0.0274
Maximum health deficits	$\bar{d}$	0.1005
Capital share	α	0.3
EOS between capital and labor	ξ	0.5
Depreciation rate of capital	δ	0.05

The values for the flexible parameters are provided below in Table 2. The medical effectiveness and environmental parameters, Q and a, are chosen to calibrate average health care spending, the aggregate health care expenditure share (H/Y), and life expectancy ($\hat{Z}$). The labor and capital-augmenting technologies, A_L and A_K, are chosen to match real GDP per capita, and the consumption and investment shares (C/Y and I/Y). The world interest rate, r, is chosen in each period to calibrate the benchmark net export share. The non-health government expenditure and the public health care expenditure shares (i.e. g and σ_g) are chosen to match the corresponding ratios in the data. Finally, the capital, labor, and consumption tax rates match tax data from McDaniel (2007).

Table 2: Flexible Parameters (Calibration)

Description	Notation	1995-2004	2010-2019	%Δ
Medical effectiveness	Q	0.000233379	0.000274522	17.63%
Environmental parameter	a	-0.0199477	-0.0205261	-2.90%
Labor-augmenting technology	A_L	56191.6	65492.6	16.55%
Capital-augmenting technology	A_K	0.164386	0.165895	0.92%
World interest rate	r	0.0599735	0.0589512	-1.70%
Government expenditure output share	g	0.1882	0.1961	4.20%
NHS share of health expenditures	σ_g	0.790	0.806	2.03%
Tax rate on capital	τ_k	0.266	0.267	0.38%
Tax rate on labor	τ_l	0.235	0.255	8.51%
Tax rate on consumption	τ_c	0.156	0.170	8.97%

Table 3 below displays the sample averages for various aggregate variables from each reference period, along with the corresponding values from the benchmark specification of the model. As Table 3 indicates, the model closely matches the data in each period. The equilibrium per capita values for real GDP (y) and health care spending (h) tightly match their sample averages, while per capita consumption (c) is within a few hundred pounds of its sample averages. Naturally, the GDP shares are also very close matches with the sample averages. Given that the focus of the model is on the relationship between health care demand and capital flows, I intentionally match the model to the health expenditure and net export shares. Likewise, non-health government spending is treated as exogenous, allowing me to exactly match the observed average government spending share. This means that the consumption and investment spending shares deviate slightly from their sample averages.[6] The model replicates the average age at retirement, R, which was 37.75 in 1995-2004 and

[6]Note that the volatility of all five spending ratios in the data implies that the sample averages will not sum to 100%, which also accounts for a portion of the disparity between the benchmark values for C/Y and I/Y and their corresponding values in the data.

39.82 in 2010-2019 (calendar age 57.75 and 59.82, respectively). Finally, the equilibrium life expectancy at age 20 in each period match the sample averages of 58.34 and 61.34.

Table 3: Calibrated Model vs. Data

	1995-2004		2010-2019	
Variable	Data	Model	Data	Model
y	£24,781.51	£24,781.50	£29,195.31	£29,195.30
c	£13,821.76	£13,718.90	£15,914.08	£15,680.80
h	£1,727.82	£1,709.91	£2,855.46	£2,855.31
C/Y	55.75%	55.36%	54.50%	53.71%
H/Y	6.90%	6.90%	9.78%	9.78%
I/Y	16.07%	17.45%	16.58%	17.44%
G/Y	18.82%	18.82%	19.61%	19.61%
N/Y	1.47%	1.47%	-0.54%	-0.54%
R	37.75	37.75	39.82	39.82
$\hat{Z}$	58.34	58.34	61.45	61.45

This completes the calibration of the model. The next section contains the numerical analysis of the model. This exercise involves analyzing the steady state response of the economy to two separate shocks, the first of which simulates a medical innovation that increases medical effectiveness (i.e. Q), and the second, which simulates income growth in the form of an increase to the labor-augmenting technology A_L. Each of these events have been identified in the literature as major contributors to the rise of the output share of health, and therefore help address the primary research questions of this study.

4 Numerical Analysis

Understanding how international finance impacts the model requires comparing the benchmark open economy model's predictions with that of a closed economy version of the model. By assumption, the closed economy model does not allow trade, implying that $f(z) = 0$, there is no trade imbalance, and all government debt must be financed domestically. These assumptions eliminate equations (9), (24), and (25) from the model. This means that there are some fundamental differences between the two versions of the model that makes a direct comparison challenging. Therefore, to ensure that the two versions of the model are comparable, I calibrate the closed economy model to match the open economy model as closely as possible. Specifically, I adjust Q, a, A_L, and A_K to match steady state per capita health expenditures and GDP, the steady state retirement age, and life expectancy from the open economy model. The new values for these parameters are provided below in Table 4.

Table 4: Flexible Parameters (Closed Economy)

Description	Notation	1995-2004	2010-2019	%Δ
Medical effectiveness	Q	0.00022415	0.000278928	24.44%
Environmental parameter	a	-0.0199862	-0.0205058	-2.60%
Labor-augmenting technology	A_L	54187.5	66438.7	22.61%
Capital-augmenting technology	A_K	0.176023	0.161613	-8.19%

A quick comparison of Tables 2 and 4 reveals some small differences in the calibrated values of these parameters. Initial Q and A_L are higher in the closed model, while A_K actually declines between periods. While possible, the decline of A_K is surprising and implausible as it implies that capital became *less* productive between the two time periods. Likewise, while the two versions of the model agree that Q and A_L increased between the two time periods, calibrating the closed model to match the 2010-2019 data requires a greater increase of Q and A_L between the two periods. This is the first piece of evidence supporting the claim that open economy assumptions improve the model's fit.

The steady state values for the two versions of the model in each time period are compared below in Table 5. While the two models are close matches with each other in most respects, the consumption and savings behavior of the two models differs in some significant ways. Naturally, in the closed model, since trade isn't permited and H/Y and G/Y are calibrated to match the data, the foreign lending/borrowing in the open model will end up being divided between either consumption or saving in the closed model. For example, in the 1995-2004 steady state the net export share is 1.47%, implying that the UK was a net foreign lender. Without access to foreign asset markets, agents in the closed economy will base their savings and consumption decision on the domestic real interest rate r_k, which is no longer restricted by the world interest rate r. In response, agents consume more and save less, causing C/Y to increase by 2.05 percentage points, while I/Y declines by 0.58 percentage points relative to the open model.

Conversely, in 2010-2019, when the UK ran a negative trade balance, the consumption and investment shares move in the opposite direction, with C/Y falling below the open economy level, implying that agents consume less and save more. Note that this slighly biases the welfare measures. Individual and aggregate welfare in the closed model is slightly elevated above the open model in 1995-2004 and slightly below in 2010-2019. This indicates that the closed model tends to understate the responsiveness of consumption, causing the welfare inferences to be biased.

Table 5: Calibrated Equilibrium (Open Economy vs. Closed Economy)

	1995-2004		2010-2019	
Variable	Open	Closed	Open	Closed
y	£24,781.50	£24,781.40	£29,195.30	£29,195.40
c	£13,718.90	£14,228.10	£15,680.80	£15,456.50
h	£1,709.91	£1,709.92	£2,855.31	£2,855.31
C/Y	55.36%	57.41%	53.71%	52.94%
H/Y	6.90%	6.90%	9.78%	9.78%
I/Y	17.45%	16.87%	17.44%	17.67%
G/Y	18.82%	18.82%	19.61%	19.61%
N/Y	1.47%	0.00%	-0.54%	0.00%
R	37.75	37.75	39.82	39.82
$\hat{Z}$	58.34	58.34	61.45	61.45
$V(0)$	190.20	190.93	194.63	194.34
Ω	549.22	551.30	586.23	585.37

4.1 Medical Innovation

For this study, I am concerned with answering two questions: To what degree has the rise in health demand contributed to the decline of the UK's current account? And, how does the introduction of open-economy macroeconomics impact the model? Medical innovation is one of the primary causes of rising health shares. Medicine has advanced rapidly over the past century, with new pharmaceuticals, medical devices, and treatments being developed at an incredible pace. Each of these innovations stimulates demand by improving the quality of current health care goods and services, or by making previously untreatable conditions treatable, which in turn has increased longevity, creating further demand for health care. Therefore, in this experiment, I adjust Q to simulate the effects of medical innovation alone on the economy. Specfically, I assume that the initial level of medical technology increases by 17.63%, which is equivalent to the percent increase of Q that occurred between the sample periods in the open model (see Table 2 above). Put differently, this experiment assumes that medical improvements were the only change that occurred in the economy between 1995-2004 and 2010-2019. In this scenario, the innovations in health care motivates agents to invest more into their health, leading to a rise in H/Y.

In each experiment, I evaluate how the economy responds under three different NHS finance regimes; (i) deficit spending, where all new NHS expenditures are financed using government debt, (ii) a balanced budget rule, where all new expenditures are financed through consumption taxes, and (iii) a different balanced budget rule, where all new expenditures are financed through income taxes. I then repeat this exercise for the closed economy model. The percent change of steady state GDP, consumption, and health expenditures per capita, along with the expenditure shares, the retirement age, life expectancy, and the welfare measures following the change to Q are presented in Table 6.

Table 6: Medical Innovation

	Open			Closed		
Variable	Deficit	$\Delta\tau_c$	$\Delta\tau_l$	Deficit	$\Delta\tau_c$	$\Delta\tau_l$
y	-0.40%	-0.40%	-0.39%	2.35%	0.68%	-0.33%
c	0.15%	-2.00%	-2.68%	-0.14%	-2.01%	-2.59%
h	23.20%	23.14%	18.39%	22.17%	22.71%	18.51%
C/Y	0.55%	-1.60%	-2.29%	-2.43%	-2.67%	-2.27%
H/Y	23.69%	23.64%	18.86%	19.37%	21.88%	18.90%
I/Y	0.00%	0.00%	0.00%	0.34%	0.13%	0.01%
N/Y	-131.73%	-50.59%	-2.07%	0.00%	0.00%	0.00%
R	0.86%	0.86%	0.81%	3.24%	1.76%	0.82%
$\hat{Z}$	1.26%	1.26%	1.21%	1.22%	1.22%	1.16%
$V(0)$	0.32%	0.08%	-0.01%	0.00%	-0.04%	-0.01%
Ω	1.35%	1.12%	0.99%	0.94%	0.94%	0.94%

There are numerous important takeaways from Table 6. The large increase in medical effectiveness in this scenario results in a large increase in health care demand, with per capita health care spending rising by 18.39% on the low end to 23.2% on the high end. The medical innovations, combined with the rise in health spending has a positive effect on life expectancy, increasing it by 1.16-1.26%. The rise in life expectancy motivates workers to delay retirement by a little over 0.8% in the open model. Note, however, that the impact on labor is much greater in the closed model, especially under the deficit regime, where the respective tax rates are held constant, and the consumption/savings decision is less distorted. As a result, R increases by 3.24%, which along with a modest increase in the investment share, contributes to a 2.35% increase in GDP per capita. Once the NHS flips to a balanced budget rule, the tax increases begin to distort the optimal levels of consumption, savings, and labor, resulting in a dampening effect on y, c, and R relative to the deficit spending regime. A similar dynamic exists in the open model, but to a lesser degree.

In most cases, the effect on GDP per capita is minor, decreasing it by about 0.4% in the open model (note that GDP per capita varies more widely in the closed model). As expected, the health share will climb significantly, with the percent increase ranging from 18.86% to as high as 23.69%. In the open economy model, the increase in medical spending has a negative effect on the net export share. Not surprisingly, the largest decline of N/Y occurs under the deficit spending NHS regime, due to the twin deficit effect. Under the deficit spending policy, national savings declines as the government borrows more money to finance the additional NHS expenditures, thereby requiring more borrowing from foreign lenders. As a result, N/Y declines by 131.73% (by comparison, the observed decline of the UK's net export share was 136.73% between the two sample periods). The effect on N/Y is diminished when the NHS is restricted by a balanced budget rule. The consumption tax is less distortionary on the savings rate than the income tax. As a result, the impact on N/Y is less stark under the income tax regime. Indeed, the greater distortionary nature of income taxes causes the response of the economy to be almost identical in the two versions of the model when the NHS operates on an income tax regime.

Finally, aggregate and individual welfare gains are greatest under the deficit spending regime in the open economy model. The next preferred policy is the consumption tax regime in the open model. Notably, these are the two scenarios where the effect on N/Y is the largest. Thus, not only does foreign borrowing help facilitate additonal health spending following medical innovation, it also appears to enhance the subsequent welfare gains. This result follows from the ability of individuals and governments in open economies to borrow from sources outside of the domestic economy, and avoid having to cut consumption, investment, or government spending to finance additional health expenditures. This is particularly true when the government uses deficit spending. As Table 6 demonstrates, this is the only one of the six scenarios where C/Y actually increases following the medical innovation. This is only possible through additional foreign capital inflows that finance domestic investment and the growing NHS deficit.

4.2 Rising Income

Income growth is another significant driver of rising demand for health care. There are several potential sources of growth in the model, including shocks to the capital-augmenting technology and the world interest rate. These shocks, however, are a little more narrow, primarily impacting capital. Therefore, to simulate income growth more broadly, I have chosen to model income growth resulting from shocks to wages that are attributable to an increase to the labor-augmenting technology. I follow the same procedure as before, this time treating the 16.55% increase of A_L as the sole change between the two sample periods. The simulated response of the two models is presented below in Table 7.

Table 7: Income Growth

	Open			Closed		
Variable	Deficit	$\Delta\tau_c$	$\Delta\tau_l$	Deficit	$\Delta\tau_c$	$\Delta\tau_l$
y	16.52%	16.52%	16.52%	17.26%	16.73%	16.41%
c	16.55%	15.89%	15.67%	16.48%	15.89%	15.69%
h	23.75%	23.74%	22.45%	23.50%	23.65%	22.48%
C/Y	0.03%	-0.54%	-0.73%	-0.66%	-0.72%	-0.62%
H/Y	6.21%	6.20%	5.09%	5.33%	5.93%	5.21%
I/Y	0.00%	0.00%	0.00%	0.08%	0.02%	-0.01%
N/Y	-30.44%	-8.77%	3.53%	0.00%	0.00%	0.00%
R	0.21%	0.21%	0.20%	0.76%	0.36%	0.11%
$\hat{Z}$	0.24%	0.24%	0.23%	0.23%	0.23%	0.22%
$V(0)$	1.72%	1.66%	1.63%	1.64%	1.63%	1.63%
Ω	1.88%	1.82%	1.79%	1.78%	1.78%	1.78%

Contrary to the previous experiment, there are few differences across NHS fiscal policy regimes nor between the two models. Starting with the open model, GDP per capita rises by 16.52% in all three scenarios. Both forms of consumption rise in per capita terms, with health care spending increasing at a faster pace than GDP, causing H/Y to rise, as expected. Increased health spending contributes to a modest 0.23-0.24% increase in life expectancy. The rise in labor productivity causes the real wage rate to rise, motivating workers to delay retirement, increasing the aggregate labor supply by about 0.2%. The impact on the trade balance is relatively minor compared to the previous experiment. The most significant response occurs under deficit spending, with N/Y declining by 30.44%. As before, this change is attributable to the rise in government debt created by the 6.21% increase in health care spending relative to GDP. This is the only scenario where C/Y does not decline, implying that the increased foreign borrowing has made it possible for the economy to spend a greater share on health care without having to spend a smaller share on consumption, investment, or government purchases.

Relative to the deficit spending alternative, the consumption tax policy does not have a substantial effect on health spending. However, the increase to the consumption tax rate does cause the rise in consumption to be less pronounced, with per capita consumption increasing by only 15.89%. As a result, the consumption share declines by 0.54%. This decline in consumption spending relative to GDP partially offsets the 6.2% increase to the health care share, resulting in a smaller decline of the net export share (8.77% versus 30.44%). The rise in life expectancy and the retirement age are indentical under these two policies, so the only difference in welfare will be caused by any differences in consumption. Therefore, the welfare gains that occur in the consumption tax regime are marginally smaller.

The negative impact on the growth of consumption is slightly larger under the income tax policy. The consumption share under this policy declines by 0.73%, while the investment and government spending shares are unchanged. Growth in health spending also climbs by less, resulting in only a 5.09% increase in the health share. Though seemingly small in comparison, the decline of the consumption share is actually associated with a rise in national savings, despite the increase of the health spending share. Since the investment share is unaffected, this additional savings is lent abroad, resulting in a 3.53% increase to the net export share. Life expectancy and the retirement age both increase by roughly same amount as the other two cases. Overall, the welfare gain is slightly smaller under this policy than the other two, making it the least preferred of the three.

The closed model provides very similar predictions, with some important differences. The tax rates are unaffected under the deficit spending regime, while the marginal product of capital increases slightly. This leads to a minor increase in investment relative to GDP, and allows for a slightly larger increase to the real wage rate. As a result, labor increases by 0.76%, culminating in a 17.26% increase in GDP per capita, allowing for a greater increase to consumption per capita (16.48%) than occurs under the balanced budget policies. Medical consumption per capita rises by 23.5%, resulting in a small increase in life expectancy. Combined, the consumption share declined by 0.66%, while the health spending share increases by 5.33%. The welfare gains are slightly smaller than occur in the open model, due in large part to the larger increase in labor time in the closed model.

Switching to the balanced budget policies has similar results as occurred in the open model. Growth of GDP per capita declines relative to the deficit model as the tax increases lead to less dramatic growth of the labor supply. The tax hikes also result in less per capita growth of non-medical consumption (although it is worth noting that C/Y declines the least in the income tax regime due to the fact that GDP growth is the smallest under this policy). Health care consumption per capita grows the most in the consumption tax regime and the least in the income tax regime. Despite these differences, society is essentially indifferent between the three policies. The welfare response of the three closed scenarios is essentially equivalent to the welfare response under the income tax regime in the open model, and only slightly below that of the open consumption tax regime. Overall, the most preferred policy is again the deficit regime in the open economy model.

5 Conclusion

This study is the first to investigate how rising health expenditure shares impact foreign capital flows and, in turn, evaluate the effectiveness of foreign capital as a means for financing healthcare. To accomplish this, I incorporate the Dalgaard and Strulik (2014) health deficit model into an open economy framework to analyze the general equilibrium aggregate effects of rising health GDP shares following a medical innovation or income growth. This model is calibrated to match UK aggregates and is shown to sucessfully replicate sample averages for two separate periods, 1995-2004 and 2010-2019.

Several conclusions can be drawn from the experiments conducted in this study. First, increasing health shares tend to reduce the trade balance, including under a balanced budget rule. Second, the closed economy version of the model tends to slightly understate the welfare benefits of medical innovation and income growth relative to the open economy benchmark. And, while the difference in the welfare implications is minor, it is likely that this study itself understates the potential welfare gains from medical innovation and economic growth due to the assumption that health does not impact productivity and only affects utility indirectly through its relationship with longevity. Perhaps with more comprehensive assumptions about the role that health plays in society the welfare implications would be more stark. Third, in the scenarios I consider, the greatest welfare gains occur under open economy assumptions and with a deficit spending regime. This outcome suggests that borrowing for investment in health is optimal and that access to foreign capital markets allows the economy to borrow without having to sacrifice consumption, investment, or government purchases.

While this work makes strides in demonstrating the importance of foreign capital in health finance, there are still many avenues for future work in this area. To take one example, this study treats the effects of rising health spending on the trade balance implicitly. It is likely that international trade plays a more significant role on health care markets than is discussed here. For example, some countries may have a comparative advantage in the production of pharmaceuticals, medical devices, or some other exportable medical good or service, providing them with an opportunity for export these goods and services to other nations at a lower opportunity cost than their trade partners would have on their own. Trade also plays an important role in exposing nations to the latest medical technologies and techniques that are being developed overseas that may enhance the effectiveness of health care.

Additionally, there are alternative ways that international finance may impact a nation's health that have not been explored here. This study treats health production as part of the wider production of a single, generic final good. However, a more sophisticated model might differentiate between the production of non-medical goods and health care goods. This would require that healthcare producers invest in physical capital to increase production in response to a rise in health demand. Foreign capital may have an important role in providing funds for these investments.

Conflict of Interest The author declares no conflict of interest.

Data Availability The main datasets for this study are publicly available from the OECD Data Explorer, the UK Office of National Statistics (ONS), and McDaniel (2007). OECD data can be accessed at https://data-explorer.oecd.org/. Data obtained from the UK ONS are provided at https://www.ons.gov.uk/. Updated data from McDaniel (2007) can be accessed at https://www.caramcdaniel.com/research.

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