CHAPTER 11

CLIMATE CHANGE AND INTERGENERATIONAL WELL-BEING

JEFFREY D. SACHS

11.1 Introduction

The problem of climate change is typically discussed as a problem of intergenerational well-being. Current generations are called upon to make sacrifices today for the well-being of future generations. These sacrifices arise in the form of the increased costs of mobilizing low-carbon energy systems (such as renewable energy and carbon capture and sequestration) to cut carbon emissions and thereby reduce the buildup of climate change in the future.

The case for climate change mitigation is therefore dependent on how the well-being of today's generation is weighed against that of future generations. As usually discussed, this in turn hinges on the social discount rate, according to which the well-being of future generations is weighted relative to that of those alive today. If the discount rate is high, so that future well-being is not accorded much importance relative to that of the current generation, then the case for investing in climate change mitigation (i.e., the reduction of greenhouse gas [GHG] emissions) is thereby reduced. The paradox is that even if the social discount rate is as low as 3% per annum, the weight accorded 100 years in the future relative to today is a mere 5%, equal to 1 divided by (1.03) raised to the 100th power. This would seem not to give much importance to future well-being, and therefore not to give too much importance to the calls for climate control.

Of course we don't sit very comfortably with such a conclusion. Something isn't correct about the geometric discounting operation. It may be that 3% per annum is too high. Some ethicists call for much lower social discount rates, even zero, to reflect the moral symmetry of those living today with future generations. Some say that the discounting should really be represented as a kind of hyperbolic discounting, with just one step between "today" and the "future," rather than as continuous geometric discounting into the distant horizon. As just one example of this logic, we may care roughly the same about three generations in the future and six generations in the future, suggesting that we don't really discount the three extra generations using a factor such as 3% per annum between those two distant generations.

There is a wholly different reason for avoiding the overemphasis on a social discount factor to calibrate the interests of different generations. Society can use intergenerational fiscal transfers to allocate the burdens and benefits of climate change mitigation across generations without the need to trade off one generation's well-being for another's. This is an option too rarely considered in the current policy debate.

In the simplest terms, it comes down to this. If climate change is important for future generations, but costly action is needed today, then it may be possible to fund today's actions with public debt, so as to shift the ultimate costs of mitigation to later generations. In this way, climate change policy is not really a tradeoff of current well-being and future well-being. It is instead a tradeoff of climate change versus taxation facing future generations.

This chapter illustrates this proposition with two very simple overlapping generations models, designed to make a simple point. Climate change mitigation policy should be discussed alongside intergenerational public finance. In this way, it may be possible to construct mitigation policies that are Pareto improving for all generations relative to a business-as-usual (BAU) scenario of no climate change mitigation.

11.2 A TWO-PERIOD ILLUSTRATION

Consider a simple two-period model, with periods indexed by $t = 1, 2$. A young generation today lives for periods 1 and 2. This young generation works in the first period and retires in the second. The current young generation saves part of its disposable wage income for consumption in the second period. Another young generation is born in period 2 and works and lives just in the second period. In each period, the young workers earn a pre-tax wage $w(t)$ and pay taxes $T(t)$. If $T(t) < 0$, the government is making a net transfer to the young workers of generation t.

The wage in the first period depends on climate policy. The economy emits GHGs. In the BAU scenario of no climate change control, emission are E. There is an emissions mitigation technology $M(1)$, with $0 \leq M(1) \leq 1$, so that emissions net of mitigation are $[1 - M(1)]E$. The government chooses the level of M through regulatory policies imposed on the private sector.

Because mitigation is costly, the market wage w_1 is reduced by the use of mitigation technology:

$$w(1) = W - \lambda M(1) \tag{11.1}$$

GHG concentrations in period 2 are determined by the emissions in period 1:

$$G(2) = [1 - M(1)]E \tag{11.2}$$

Wages of the young in the second period are reduced by climate change, which is proportional to the level of GHGs. Thus, as shorthand we can write that wages are directly dependent on the level of GHGs:

$$w(2) = W - \theta G(2) \tag{11.3}$$

The disposable labor income of each young generation is equal to the market wage net of taxes:

$$Y(t) = w(t) - T(t), \quad t = 1, 2 \tag{11.4}$$

Suppose that the government makes transfers to the young today, $T(1) < 0$, by selling bonds $B(2)$ and then redeems those bonds by taxing the youth of the second generation. Thus, $B(2) = -T(1)$ and $T(2) = (1 + r)B(2)$, where r is the rate of interest on the bonds. Clearly, the government's two-period budget constraint is:

$$T(1) + T(2)/(1 + r) = 0 \tag{11.5}$$

Note that we can write the second-period disposable labor income in terms of first-period mitigation and tax policies by collecting terms (11.2)–(11.5):

$$Y(2) = W - \theta[(1 - M(1)]E + T(1)(1 + r) \tag{11.6}$$

Finally, note that workers of the first generation consume $C1$ when they are young and $C2$ when they are old. They save part of their disposable labor income s in the form of bonds and claims to physical capital, with the saving rate presumably chosen to maximize lifetime utility. Therefore:

$$C1(1) = (1 - s)Y(1) \tag{11.7}$$

$$B(2) + K(2) = sY(1) \tag{11.8}$$

We assume that physical capital earns a constant net rate of return r and that government bonds must also therefore pay the same rate of return. Thus, the consumption of today's young when they are old in the second period is:

$$C2(2) = (1 + r)[B(2) + K(2)] \tag{11.9}$$

The young of the second period simply consume their disposable labor income:

$$C1(2) = Y(2) \tag{11.10}$$

Suppose that there are L workers in each generation. Total GDP in period 1 is therefore:

$$Q(1) = w(1)L \tag{11.11}$$

Total GDP in period 2 is the sum of labor income and net capital income:

$$Q(2) = w(2)L + rK(2) \tag{11.12}$$

Finally, let us specify the lifetime utility of each generation according to their lifetime consumption levels. For the first-period young, $U_1 = U_1[C1(1), C2(2)]$. For the second-period young, $U_2 = U_2[C1(2)]$. If these utility functions are well behaved, we can write the utility of each generation more simply as a function of their disposable labor income:

$$U_i = U_i[Y(t)] \tag{11.13}$$

Now, we are finally ready to make some basic observations about climate policy. Collecting terms, the well-being of the first-period young generation is given by:

$$U_1 = U_1[W - \lambda M(1) - T(1)] \tag{11.14}$$

The well-being of the second generation is:

$$U_2 = U[W - \theta[1 - M(1)] + T(1)(1 + r)] \tag{11.15}$$

Now let us turn to optimum climate policy. Let us start with the case of balanced budgets, $T_1 = T_2 = 0$. In this case, climate change poses a direct intergenerational conflict. The first generation wants $M(1) = 0$ while the second generation wants $M(1) = 1$. Suppose that the government must decide on $M(1)$. We can imagine two scenarios. In the case of a wise central planning government, the proper outcome is to maximize a Social Welfare Function (SWF) that is a function of the well-being of each generation:

$$\text{SWF} = V(U_1, U_2) \tag{11.16}$$

A utilitarian might represent this in additive form:

$$\text{SWF} = U_1 + U_2/(1 + \delta) \tag{11.17}$$

where δ is the pure rate of social discount in the SWF, with a value between -1 (all weight to the future) and infinity (all weight to the present). The social planner would then select $M(1)$ to balance the interests across the two generations. If δ is very high, the optimum $M(1)$ will be close to zero. If δ is just slightly greater than -1, then all of the weight is put on the future, and $M(1)$ will be close to 1.

An alternative view of government, at least in the electoral democracies, is that government represents the interests of the voters. If the voters vote to maximize their own well-being, today's young generation would vote for $M(1) = 0$. The unborn next generation does not vote in first-period elections. Thus, representative government would choose to have no mitigation, the so-called BAU trajectory.

There is a third possibility, however, that is typically ignored or underplayed. That is to use intergenerational fiscal transfers to improve upon the BAU trajectory. Suppose that we begin at BAU and ask whether there is some combination of taxes, transfers, and mitigation policies that can leave each generation better off than in the BAU trajectory. The answer is yes if climate change is sufficiently costly relative to the costs of mitigation. Consider a mitigation policy that is funded with debt, leaving the current generation with unchanged disposable income. Specifically, set $T(1) = -\lambda M(1)$ so that the young workers of the first generation receive transfer payments from the government that exactly offset the costs of mitigation. We see that $Y(1) = W$, the same as on the BAU trajectory when $M(1) = 0$.

Now consider the situation of the second generation. $Y(2) = W - \theta[1 - M(1)]E + T(1)(1+r) = W - \theta[(1 - M(1)]E - \lambda M(1)(1+r)$. We see that second-period disposable labor income $Y(2)$ is an increasing function of $M(1)$ if and only if $\theta E/(1+r) > \lambda$. That is, if the present value of the benefit of a unit of mitigation, given on the left-hand side, is greater than the marginal cost of mitigation, given on the right-hand side, then mitigation should be undertaken. In that case, given the linearity assumptions of this simple model, all emissions are abated, with $M(1) = 1$.

Let us assume that the fundamental case for climate change mitigation applies, that is, that $\theta E/(1+r) > \lambda$. Then the young generation can vote a mitigation strategy and transfer policy that is financed by government debt. The next generation will repay that debt by taxes on labor income. Today's young generation is left unharmed. The second-period young generation is made better off. Mitigation policy is Pareto improving across the two generations.

11.3 AN OVERLAPPING GENERATIONS FRAMEWORK

Let us now generalize these results, by considering an overlapping generations (OLG) model in which every generation $t = 1, 2, 3, \ldots$ lives for two periods, working and paying taxes while young and consuming while old. The same principles apply as in the two-period model. Climate change would seem to pit today's young generation against future generations. An intergenerational tax-and-transfer policy, however, can eliminate the intergenerational conflict, and turn climate change mitigation into a Pareto improving strategy.

Individuals of generation t live for two periods, t and $t+1$. They consume $C1(t)$ when young and $C2(t+1)$ when old. The population is unchanging and normalized to be L in each generation.

The production function is:

$$Q(t) = w(t) + rK(t) \tag{11.18}$$

where $w(t) = W - \theta G(t) - \lambda M(t)$ and W is a fixed gross wage, $G(t)$ again stands for GHGs as of period t, and $M(t)$ again stands for the mitigation effort in period t, ranging from zero to 1. $K(t)$ is the capital stock in period t, owned by the old generation. We again assume that the net return on capital r is fixed.

As in the two-period model, $T(t)$ is the tax paid by members of the young generation at time t. If $T(t)$ is negative, the young in generation (t) receive a transfer from government. The government finances its taxes and transfers through sales of government bonds $B(t)$. All taxes and transfers, for simplicity, are assumed to occur in youth. Disposable income of the young is:

$$Y(t) = w(t) - T(t) \tag{11.19}$$

One-period government bonds $B(t)$ pay net interest r, which is the same as the net return on physical capital. The government's intertemporal budget constraint is

$$B(t+1) = (1+r)B(t) - T(t) \tag{11.20}$$

where $T(t)$ equals net taxes.

The government cannot borrow in a Ponzi scheme, meaning that the government's intertemporal budget constraint must be satisfied. This budget constraint states that the present discounted value of net taxes must be non-negative.

$$\sum_{t=0}^{\infty} (1+r)^{-t} T(t) \geq 0 \tag{11.21}$$

Let $Y(t)$ stand for $w(t)$ net of $T(t)$. The young household saves $Y(t) - C1(t)$ at time t, which goes into a portfolio of capital and bonds (which are perfect investment substitutes):

$$K(t+1) + B(t+1) = Y(t) - C1(t) \tag{11.22}$$

Second-period consumption is given by the value of wealth in the second period:

$$C2(t+1) = (1+r)[K(t+1) + B(t+1)] \tag{11.23}$$

The utility of generation t is given by

$$U(t) = U[C1(t), C2(t+1)]$$

We assume that $U(C1, C2)$ is a homothetic function, specifically the discounted sum of isoelastic utility functions:

$$U(t) = [C1(t)^{(1-\sigma)}]/(1-\sigma) + \beta[C2(t+1)^{(1-\sigma)}]/(1-\sigma) \tag{11.24}$$

The budget constraint of generation t is:

$$C1(t) + C2(t+1)/(1+r) = Y(t) \tag{11.25}$$

Because of homothetic tastes and constant r, $C1(t)$ and $C2(t)$ are fixed multiples of $Y1(t)$

$$C1(t) = (1 - s)Y(t) \tag{11.26}$$

$$C2(t+1) = s(1+r)Y(t) \tag{11.27}$$

Because $U(t)$ is therefore proportional to $[Y(t)]^{(1-\sigma)}$ we can again take $Y(t)$ as an index of the lifetime utility of generation t as we did in the two-period model.

11.4 CLIMATE CHANGE

Now suppose that this economy is vulnerable to climate change, according to the following dynamics. Emissions in any period are at level $[1 - M(t)]E$ where $M(t)$ is the proportion of mitigation in period t, $0 \leq M(t) \leq 1$. Because there is no direct incentive for any individual firm to abate its emissions, mitigation control is set in a political process, voted by the currently alive generation.

GHGs accumulate according to

$$G(t+1) = (1-\delta)G(t) + [(1 - M(t)]E \tag{11.28}$$

Note that a fraction of GHGs δ naturally leaves the atmosphere each period to a long-term marine or terrestrial sink. In the absence of new emissions, therefore, the GHG concentration decays exponentially.

The losses each period associated with GHG concentration $G(t)$ is $\theta G(t)$, and these losses are assumed to come out of wages. The cost of mitigation is $\lambda M(t)$, which also is borne by wages. Thus, the net disposable income of the young is therefore:

$$Y(t) = W - \theta G(t) - \lambda M(t) - T(t) \tag{11.29}$$

Note that as in the two-period model, in the absence of intertemporal fiscal policy no generation has an incentive to support mitigation. Each young generation takes as given the prevailing GHGs at time t, and any mitigation cost would have to come out of contemporaneous wages. The older generation, which is living off of its savings, is assumed to be unaffected by $G(t)$ or $M(t)$ in a direct way, and is therefore indifferent to mitigation. Thus, if put to a vote by today's living generations, $M(t)$ would be set equal to 0 in each period t. $G(t)$ would grow over time, asymptotically approaching E/δ. This is an inefficient outcome if θ is high enough and λ is low enough to justify mitigation. Later generations end up *unnecessarily impoverished* by the lack of mitigation. The outcome is intergenerationally inefficient.

11.5 INTERGENERATIONAL FISCAL POLICY TO THE RESCUE

A better approach is found as follows. We first calculate the no-mitigation path of $G(t)$, assuming (for notational simplicity but with no other implication) that $G(0) = 0$.

$$G(t) = E\sum_{0}^{t-1}(1-\delta)^i = E * (1/\delta)[1-(1-\delta)^t] \tag{11.30}$$

In the event of no mitigation and no fiscal transfers, income of the young is therefore:

$$Y^{NM(t)} = W - \theta E(1/\delta)[1-(1-\delta)^t] \tag{11.31}$$

In the event of full mitigation, $M(t) = 1$, and no fiscal transfers, income of the young is:

$$Y^{FM(t)} = W - \lambda \tag{11.32}$$

Now, suppose that the government proposes a policy of full mitigation, $M(t) = 1$ for all t, starting at $t = 0$ and proposes also to tax each generation in the amount

$$T(t) = Y^{\mathrm{FM}} - Y^{\mathrm{NM}} = \theta E(1/\delta)[1-(1-\delta)^t] - \lambda. \tag{11.33}$$

This policy compensates each generation for the full-mitigation program, in the sense that $Y(t)$ is the kept the same as in the *no-mitigation baseline*. It is feasible if the proposed discounted time path of taxes is indeed positive. In that case, the government would actually distribute part of the "excess taxation" to each generation, leaving every generation absolutely better off than in the BAU trajectory without mitigation.

Note that in the early periods, when t is small, the taxes are negative. The government subsidizes early generations to compensate for the up-front costs of mitigation. The taxes on later generations are positive, as those later generation would be willing to pay to avoid the high costs of climate change relative to a BAU path.

Thus, we need to check that the proposed policy $T(t)$ in (11.33) is indeed feasible in the sense of the inequality in (11.21). After some algebra, it's possible to show that the discounted value of net taxes $\Sigma(1+r)^{-t}T(t)$ is non-negative (and hence feasible) if and only if:

$$\theta E/(r+\delta) \geq \lambda \tag{11.34}$$

The left-hand side expression $\theta E/(r+\delta)$ is the discounted social cost of an increment of emission in the current period, taking into account the discount rate r and the natural rate of dissipation of GHGs δ. The right-hand side is the current cost of abating an increment E of emission. If (11.34) holds, it is indeed efficient (i.e., cost-effective for society in a discounted inter-temporal sense) to abate emissions. And if that is the case, fiscal policy can redistribute the burden so that all generations are at least as well off with mitigation as with no mitigation. If (11.34) is a strict inequality, then at least one generation can be made better off while leaving all other generations unchanged.

The conclusion is that if mitigation is intertemporally efficient, as in (11.34), then it is also possible to design an intertemporal fiscal scheme in which each generation is at least as well off with mitigation as without mitigation. Early generations get subsidized to undertake mitigation while later generations get taxed to service the debt on the early subsidies. Assuming a strict inequality in (11.34), all generations can indeed be made better off than in the non-mitigation baseline.

11.6 A NUMERICAL ILLUSTRATION

Consider the following parameter values, adopted for illustration and without any pretense of realism:

$$\begin{aligned} W &= 100 \text{ (pretax wage of the young)} \\ E &= 1 \text{ (emission level)} \\ r &= 0.5 \text{ (one-period interest rate)} \\ \delta &= 0.25 \text{ (one-period dissipation of GHGs)} \\ \theta &= 10 \\ \lambda &= 5 \end{aligned}$$

Generational utility is $U(t) = \ln[C1(t) + 0.5\ln[C2(t+1)]$. The consumption function is then given by $C1(t) = (2/3)Y(t)$ and $K(t+1) + B(t+1) = (1/3) * Y(t)$.

In the event of no mitigation, GHG concentrations rise from 0 to 4, and damages rise from 0 to 40. The path of $Y(t)$ is shown as the declining path in Figure 11.1. If mitigation is undertaken starting in period 1, without intergenerational fiscal policy, the first generation bears the burden on behalf of later generations. This is shown in Figure 11.2, which shows $Y^{\mathrm{FM}}(t)$ with mitigation minus $Y^{\mathrm{NM}}(t)$.

We now introduce a feasible path of fiscal policy, with subsidies in the early periods enough to more than compensate for the cost of mitigation, financed by taxes in the later periods, such that the discounted value of net taxation as in (11.21) is exactly 0 and such that every generation is better off compared with the baseline. There is, of course, no unique tax path to select, as there is a choice of how to distribute the intergenerational benefits across time. The scenario is labeled FM, for the combination of fiscal policy and mitigation policy. The chosen tax path $T^{\mathrm{FM}}(t)$ is shown in Figure 11.3. In Figure 11.4, we show the time path of

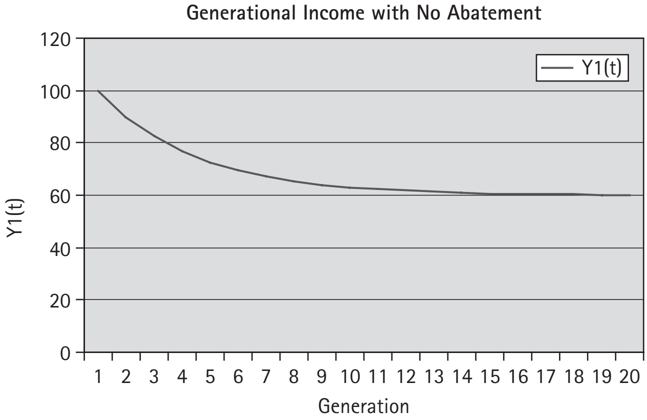

FIGURE 11.1 The baseline case (no mitigation, no intergenerational fiscal policy).

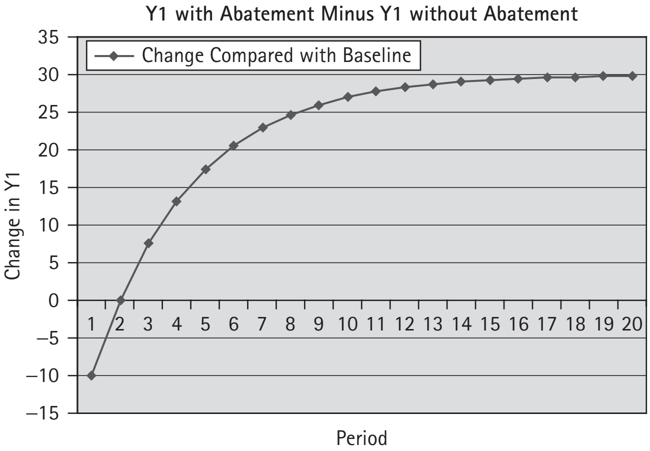

FIGURE 11.2 The change in generational income compared with baseline with mitigation and no fiscal policy.

$Y^{\mathrm{FM}}(t) - Y^{\mathrm{NM}}(t)$, demonstrating that every generation is better off than in the no-mitigation baseline.

Figure 11.5 illustrates the time paths of the capital stock in the baseline (NM) and mitigation (FM) scenarios, and the time path of government bonds $B^{\mathrm{FM}}(t)$ in the full-mitigation scenario. Remember that $B^{\mathrm{NM}}(t) = 0$ in the baseline. The fiscal policy is to run deficits in early periods, building up $B(t)$, and then to stabilize the stock of government bonds, servicing $B(t)$ through a constant level of taxation. Note that the rise of $B(t)$ partially crowds out the capital stock $K(g)$, but nonetheless leaves all generations with higher welfare than in the no-mitigation baseline.

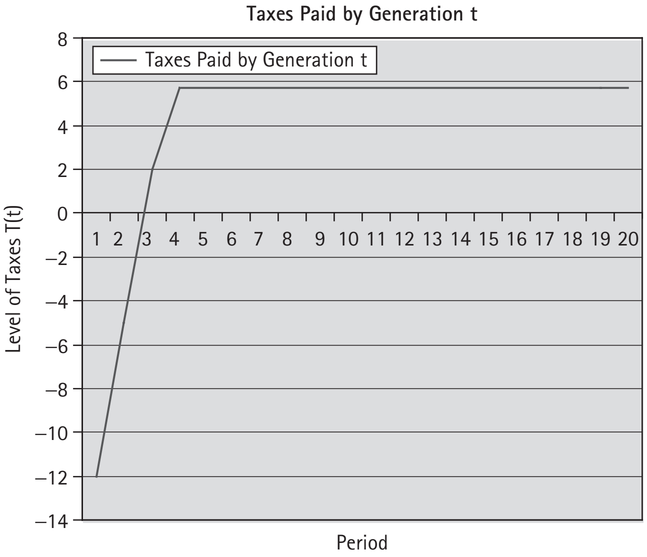

FIGURE 11.3 Time path of generational taxes to compensate for mitigation.

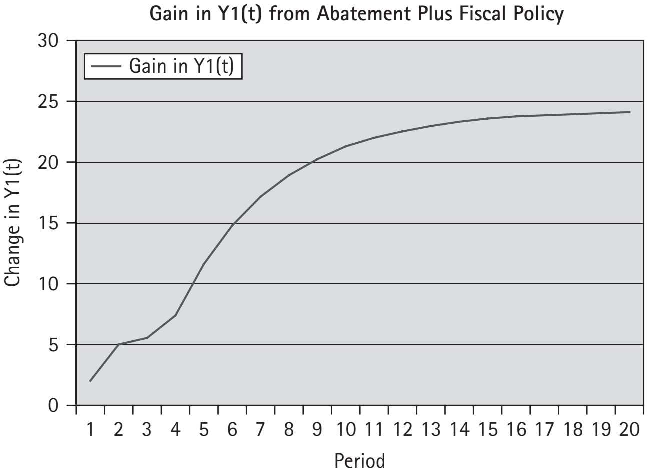

FIGURE 11.4 Rise in net generational income from mitigation with fiscal transfers.

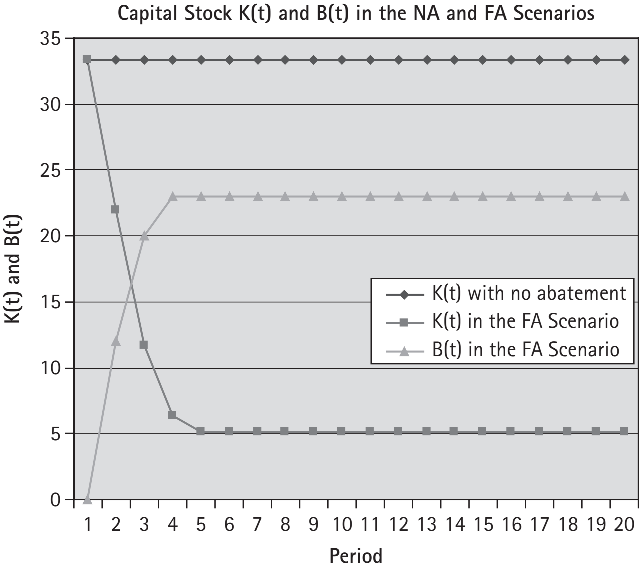

FIGURE 11.5 The time path of $K(t)$ and $B(t)$ in the NM and FM scenarios.

11.7 CONCLUSIONS AND NEXT STEPS

This chapter seeks to add an underexamined dimension to the climate change policy debate. The current debate tends to pit today's generation against the future, calling on the current generation to make sacrifices on behalf of future well-being. This chapter shows a different interpretation. The current generation can choose debt-financed mitigation to remain as well off as without mitigation, but to improve the well-being of future generations. In this sense, the current generation is acting like a steward for the future, not sacrificing for it, but still orienting public investments for the sake of future well-being.

Of course when the future arrives, later generations might not feel too happy by this scenario. They will be paying high taxes imposed on them by the choices of earlier generations. They may well resent these taxes as they would not feel clearly the benefits of avoided climate change. In the scenario depicted in the OLG example, future generations are indeed less well off than earlier generations in the full-mitigation scenario, though better off than they would have been in the no-mitigation scenario. Whether or not this wins the praise and thanks of the ancestors is hard to say!

Of course I have just sketched a simple example here without delving deeply into the intergenerational politics. Is the tax-transfer-mitigation system here indeed time consistent? Will later generations continue the policies selected by the preceding generations? Are these considerations empirically relevant if we look at the real time horizon of climate policies? These are all good questions for follow-up studies.