12. Stripping resources and investing abroad: a path to sustainable development?

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INTRODUCTION

Behind this provocative title lies a fairly simple idea. Developing a dynamic economy optimally requires every sector of the economy to be used optimally. But developing an economy sustainably does not generally need every sector to be used sustainably, unless each and every sector is vital for survival. So in most cases it is very difficult, perhaps impossible, to derive logical, watertight rules for sustainable development which can be applied operationally at a purely sectoral level. Trying to find, as many have done in recent years, coherent rules for sustainable cities, sustainable transport, sustainable water, sustainable agriculture, sustainable forests and so on, will therefore usually give disappointing and often inconsistent results. Such rules may even provide a new disguise behind which special interests can argue for protecting a sector merely for its own sake, rather than for the sake of sustaining the whole economy.

This problem, that sustaining all the parts may not be needed in order to sustain the whole, was raised informally by Pezzey (1989, pp. 55–9 and 1992, pp. 347–9) and also by Little and Mirrlees (1990, p. 365) and Beckerman (1994, p. 195), among others. I suspect that one could develop a general theorem, which states the precise conditions under which sectoral sustainability is not necessary for sustaining the whole economy. However, what follows here is just one, formal illustration of such a theorem. It is a result for an economy with three main features, which are quite realistic for many countries. First, it is a ‘capital-resource economy’. That is, it possesses both human-made capital, and depletive natural

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resources which could be renewable or non-renewable. (In this chapter 'capital' is always human-made, and a 'resource' is always natural.) Second, it is 'open' to the rest of the world, so that it exports and imports produced goods and resources. Third, it is 'small' in comparison to the rest of the world, so that nothing it does can affect the world prices of natural resources, or the world interest rate. Given further, maybe unrealistic features, such an economy can then develop sustainably by stripping (depleting) some or even all of its resources, investing enough of the proceeds abroad, and ultimately living on the interest on these investments.

In fact, the formal result found here is even stronger. It is that such an economy's plan for its future – its 'intertemporal welfare goal' – typically has no effect at all on how it manages its natural resources. Suppose it was originally planning to deplete some of its natural resources down to zero, in pursuit of a conventional goal of 'optimal development' which discounts the wellbeing of future generations. Then suppose it has some kind of ethical revolution, and all its citizens change their goal to sustainable development. The result is that the economy still manages its resource sectors in exactly the same way. All that changes is that it saves and invests more abroad, so that it can sustain its future welfare once its resources are gone.

Such a result obviously conflicts with some of the strongest traditions in the 'environmental sustainability' literature. These propose three key rules for sectoral sustainability: to sustain renewable resources, to sustain the environment's assimilative capacity, and to deplete non-renewables only as fast as they can be substituted for (see, for example, Pearce 1988, p. 58 and Daly 1990, pp. 2 and 4). This conflict will be discussed in the conclusions, but first the 'strip resources and invest abroad' result for a small open economy must be explained. This is done next in words, with the formal underlying mathematics in an appendix. Then we see what happens if the economy is closed, or large and open. Then we discuss the fallacy of composition that would occur in the result if all economies tried to strip resources and invest abroad at once. Finally, we consider the implications of all this for the broader sustainability debate.

THE RESULT FOR A SMALL, OPEN ECONOMY

Three basic assumptions about the economy have already been mentioned. It has one non-depreciating, human-made capital stock and a number of depletable, natural resources, with initial stocks of both being given. It is open to trade and is small in relation to both resource and capital markets in the rest of the world. The following further assumptions, some highly restrictive, are then needed to derive the result (see the appendix for mathematical details):

1. The natural resources, which could be non-human species, do not have intrinsic rights to be sustained or preserved for their own sake. So we are ignoring any 'deep green' philosophy that resources do have rights.

2. The resources are renewable. However, the result is in fact unaffected by the natural growth rate of the resource, and also applies to non-renewable resources, where the growth rate is zero.

3. The economy lasts just two time periods, and then ceases to exist.

4. The economy has a production process which transforms inputs of a capital stock and resource flows into a flow of a composite good. The good can be consumed in either time period; invested at home in the first period to increase the second-period capital stock; or invested abroad in the first period to yield a fixed, world rate of interest.

5. There is no limit beyond which capital cannot substitute for resources in the production process, but some resource input to production remains essential.

6. The economy has a 'representative agent'. This means that everyone in the economy is assumed to be identical, so that issues of within-generation equity are ignored.

7. The representative agent's intertemporal welfare depends solely on his or her first- and second-period consumption of the composite good. Neither resource stocks nor resource flows directly affect intertemporal welfare. That is, the resources have no environmental (non-market) value.

8. The economy is said to be sustainable if consumption is not lower in the second period than in the first. 'Sustainable' is thus distinct from 'environmentally sound' in that environmental quality is irrelevant. This differs from the majority of modern sustainability literature, such as Rapke (1994) and other papers in the same special issue. I discuss sustainability definitions at length in Pezsey (1997), and there distinguish 'sustainedness' from 'sustainability', but for an efficient, two-period economy these two concepts both amount to consumption not falling from the first to the second period.

9. There is no uncertainty in the economy.

A more general theory of the sectoral sustainability problem would obviously use fewer assumptions. The result here depends crucially on assumptions (5) (substitutability), (7) (materialism) and (9) (certainty), and these would be challenged by most environmentalists. They would
argue that many resources are ultimately non-substitutable, a direct source of environmental value, and subject to huge uncertainty. The degree to which these assumptions are right or wrong is a matter for important empirical or even ethical debates, to which I make no contribution here.

In the first period, the economy (or its representative agent) has four types of decision to make. First, how much of the resource to import, or to extract from its initial stock and export. Second, how much of its resource to extract and combine (together with any imported resource) at home with the given initial capital, to produce a certain amount of the good. These decisions determine the amount of production, and the resources available for the second period (after adding in natural growth between periods). The third decision is how much production to invest at home, which determines the second-period capital stock. The last is how much production to invest abroad. First-period consumption is then whatever production has not been invested.

In the second period, the only decision is how much of the resource to use for domestic production, which then determines how much to export (or import). Consumption is then the sum of domestic production, the return on the first-period foreign investment plus interest paid at the world rate, and the value of second-period resource exports.

The technical result of this model is that any change in the economy’s intertemporal welfare goal – whether to achieving sustainability, to achieving maximum constant consumption as in Solow (1974), or to just giving more weight to the future – changes only the levels of its consumption and foreign investment. It does not change either resource ‘management’ (that is, resource trade, and resource use for domestic production) or domestic investment in the economy. So, a sustainable economy does not necessarily require sustainable resource management. There is no need in this model for further, sector-specific constraints on resource management such as the ‘compensating investments’ suggested by Daly (1990) or Barbier et al. (1990). The only investment needed to compensate future generations is the build-up of foreign investment while domestic resources are depleted, along the lines of the investment that Kuwait has built up against the day that its oil runs out. Nor is there any need to use especially low discount rates for ‘environmental projects’, thus avoiding the problem of how to define such projects in practice. Only if resources are non-substitutable in an uncertain and/or unowned way will any sectoral or project-level policy for sustainability make sense. If the non-substitutability was certain below some critical threshold of a fully-owned resource (thus breaking assumption (5) but not assumption (9)), prices would become infinite at that threshold, and resources would be sustained automatically by their owners’ profitability calculations.

The result is formally proved in the appendix, but an intuitive explanation is as follows. Suppose the welfare goal is changed to a more ‘conservationist’ goal, which gives more weight to the future (that is, to period 2). This requires more saving and investment now. Because the economy is small and open, the world interest rate prevails in it, and is unchanged by any increase in the economy’s foreign investment. But resource management is determined solely by the interest rate (which producers use to compute and maximize the discounted present value of their profits), and so also remains unchanged. And if the economy tried to increase investment domestically, the interest rate earned would fall below the world interest rate, so the economy would be better off making all its extra investment abroad.

This separation of decisions about production and resource management from decisions about consumption, saving and foreign investment happens because the world interest rate is unaffected by the small open economy. It is an international version of the ‘separation’ theorem of Fisher (1930, p. 271; see also Hirshleifer 1980, p. 497). I refer to the result as ‘strip resources and invest abroad’, because managing natural resources to maximize discounted profits can easily lead to resource stripping (that is, exhausting the stock towards zero, either in finite or infinite time). This is inevitable for non-renewable resources (for example, see Dasgupta and Heal 1974), but discounted profit maximization can also result in ‘optimal extinction’ of renewable resources if the discount rate (that is, the interest rate) is high enough (Clark 1990). As already noted, investing abroad is then a better way of sustaining the economy’s consumption than investing at home.

THE RESULT FOR A CLOSED, OR LARGE AND OPEN ECONOMY

What would be the effect of introducing a more conservationist welfare goal into an economy which has the same properties as before, except that it is closed (as ultimately only the global economy is), or large in relation to the rest of the world? The answer is as brief as the previous section was long. The increase in desired saving in period 1 is now large relative to the capital market, and so would lower the interest rate. This then automatically changes the economy’s resource management policy to that which is necessary to achieve the new welfare goal (for example, sustainability), although the result is still not necessarily sustainable resource management. There is still no need for sectoral sustainability policies, as they compensating investments, or special discount rates for environmental projects.
A POSSIBLE FALLACY OF COMPOSITION IF MANY ECONOMIES ACT AT THE SAME TIME

The model described assumes that the small open economy changes its welfare goal on its own, while all the economies in the rest of the world make no change. What if, either by pure coincidence, or because of an international call such as the one issued by the 1992 Rio Earth Summit, a good proportion of the world's small, open economies change their welfare goal at the same time, say to sustainable development? Together they would amount to a large open economy. By the logic of the preceding paragraph, the equilibrium world interest rate would then change, as also would resource management and domestic investment in each economy. But if each economy assumes that all other economies have not changed their welfare goal, it will make plans which cannot in fact be realized.

To take an extreme example, suppose a two-period world consists of dozens of small, identical economies like the one formally modelled above. Suppose at first they all aim to maximize a conventional, discounted present value (PV) welfare function. By symmetry, this would result in no resource trade, and each economy would act as if closed. Suppose also that the parameters of each economy mean that consumption in period 1 would be unsustainable. Now suppose that just one of these economies adds a sustainability constraint to its welfare goal before any plans are enacted. By the theory of the previous section, the resource management and domestic investment of this one sustainable economy would be the same as all the other, unsustainable economies. It would achieve sustainability first, by saving and investing abroad in period 1; and second, by reclaiming its investment in period 2, with interest added at the unchanged world rate, as consumption goods (made from capital and resources) imported from unsustainable economies.

However, not every economy in this world can achieve sustainability in this way. If every economy tried to invest abroad at the same time, there would be no 'abroad' left to receive the investment! If every economy planned to do this in period 1, ex post there would be a significant worldwide increase in planned foreign investment. This would lower the world rate of interest, making domestic investment and resource conservation more attractive. But ex ante, if each economy does not realize the other economies' plans, it will expect too high a rate of interest. It will then save too little and deplete too much resource in period 1 to achieve its own sustainability, in a world where every other economy plans for sustainability, too. A global fallacy of composition would thus have occurred. What works as a sustainability strategy for one economy in isolation may not work for all economies together. It is thus important to investigate, possibly using the tools of game theory, whether and how such failures to make consistent sustainability plans can be avoided by world agencies and/or world futures markets. Unfortunately, this is beyond the scope of this chapter.

CONCLUDING DISCUSSION

This chapter has mainly studied a simple, two-period model of development in a small, open economy with human-made capital, depletable natural resources, no uncertainty, and many other restrictive assumptions. We saw that in this economy, adopting a new intertemporal welfare goal, such as sustainable development, typically requires no change at all in resource management or domestic investment. The economy can strip its natural resources down to nothing and still be developing sustainably, as long as it saves enough of the output from resource use and invests it abroad. This result does not hold when we change just one assumption and make the economy closed, or large and open. A new welfare goal will then require a change in resource management and domestic investment. However, this change will occur via market forces: the changed welfare goal changes saving; this changes the economy's interest rate; and a changed interest rate brings about the required change in resource management and domestic investment. So in all three types of economy (small open, closed, and large open), there is no need for sustainability policies (such as a programme of 'compensating investments', or especially low discount rates) to be targeted at specific resource sectors.

These results conflict directly with some of the 'strongest traditions in the environmental sustainability literature' mentioned in the introduction, which are worth giving in full here:

In simple terms [sustainable development] argues for (a) development subject to a set of constraints which set resource harvest rates at levels no higher than managed or natural regeneration rates; and (b) use of the environment as a 'waste sink' on the basis that waste disposal rates should not exceed rates of (natural or managed) assimilation by the counterpart ecosystems. There are self-evident problems in advocating sustainable rates for exhaustible resources, so that 'sustainability' tend to think in terms of a resource set encompassing substitution between renewables and exhaustibles (Pearce 1988, p. 58)

For the management of renewable resources there are two obvious principles of sustainable development. First that harvest rates should equal regeneration rates (sustained yield). Second that waste emission rates should equal the natural assimilative capacities of the ecosystems into which these wastes are emitted. ... The quasi-sustainable use of nonrenewables requires that any investment in the exploitation of a nonrenewable resource must be paired with a compensating investment in a renewable substitute. (Daly 1990, pp. 2 and 4)
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What are we to make of this conflict of views about sectoral sustainability? As a preliminary, recall that the word 'sustainable' has a purely intertemporal meaning here, and is quite distinct from 'environmentally desirable'. There will still be a general need for sectoral environmental policies to internalize external (non-market) costs, but that is not the issue here. Even ignoring all environmental externalities, which we have done throughout the chapter, the above conflict would remain.

The main conclusion is the trite, disappointing but important one that the truth is very complex. Justifying rules for sectoral sustainability is not as simple or obvious as Pearce or Daly claim. So much depends on the realism of the necessary assumptions, and Pearce and Daly's implicit assumptions do seem rather extreme. For example, their rules ignore trade, so they could only apply to a closed economy, and the only closed economy now is effectively the world economy. Current levels of consumption of renewable resources such as food and water are substantially in excess of minimum, non-substitutable needs in industrialized countries, and do not have to be sustained in order to achieve sustainable development as a whole.

However, the assumptions needed for my own result are just as extreme, in the opposite direction. I am certainly not claiming that they are all realistic. Indeed, by highlighting some simple, but unrealistic conditions required for the result to be true, this chapter is intended as a warning rather than a recommendation to policy makers in small open economies. To be sure that a 'strip resources and invest abroad' policy is wise, they must know with certainty that the resources have only private productive value and no intrinsic philosophical, popular amenity or publicly productive value; that capital will always be substitutable for resources in domestic production; and that few other countries are planning to adopt the same policy. If all countries followed the policy, there would be no abroad left to conserve natural resources and accept incoming investments.

So the result does not mean that such principles of 'environmental sustainability' should just be discarded. At its root, sustainability thinking is not a purely abstract, ethical concern for future generations, but a profound, practical concern that they are under threat from the way in which environmental resources are being treated by modern economies. If a country adopts a new welfare goal which gives more weight to the future, in practice it should probably make its resource management more conservative. However, this need not amount to sustaining each and every resource sector. Attention should also be given both to macroeconomic sustainability policies, such as the encouragement of higher saving and investment, and to the even trickier question of whether different countries' sustainability goals can be coordinated to avoid fallacies of composition.

Stripping resources and investing abroad

To be able to reach any firmer conclusions, appropriate extensions of the simple model presented here, and tests of their empirical validity, will be required. The most obvious extensions to consider would be a formal separation between consumers and producers; corner as well as interior solutions; the inclusion of various national, transboundary and global resources which do have environmental value, such as the ozone layer or biodiversity; and last but by no means least, uncertainty.

NOTES

1. It is the study of a change in welfare goal which distinguishes this chapter from the literature on how to maintain constant consumption in open economies with natural resources (for example, Kemp and Long 1982; Ashheim 1986; El Serafy 1988; Hartwick 1994; Vincent et al. 1997; and Mason 1997). The assumption that the new welfare goal is adopted by everyone in the economy avoids the need that occurs in Pezzey (1988, Section 7) for government policies to persuade individuals to follow the goal.

2. The formal mathematics of the appendix assumes only one resource, but as noted there, the results can readily be extended to the case of many resources.

3. However, sustainability goals can affect environmental policies which control cumulative emissions such as greenhouse gases (Howarth and Norgaard 1992).

4. In a multi-period model, I now define sustainedness as consumption not falling over time; while sustainability is consumption being no higher than the maximum sustainable level of consumption.

5. See Section 2.8 of Clark (1999) which ends 'If whaling companies expect to earn 10% on their investments and if the blue-whale population only increases by 5% per annum, the whalers could quite rationally plan to liquidate the blue-whale stocks (i.e. rationally from their point of view).

6. An example could be \( W(C_1, C_2) = C_1^\delta + C_2(1 + \delta)^{-\delta / \delta} \), using the notation of the appendix, where \( 0 < \delta < 1 \) and \( \delta > 0 \) is the discount rate for second-period instantaneous utility.

7. The whole arrangement could perhaps be seen as an example of 'exporting unsustainability' (Pearce et al. 1989, pp. 45-7). However, the cause of other countries' unsustainability that those authors envisaged was more their lack of knowledge and control of their natural resources, rather than their simple lack of desire for sustainability, which is the cause here.

8. If the resource is non-renewable (\( G = 0 \)), (12.1A.15) is an identity and (12.1A.16)-(12.1A.18) are three equations in three variables, \( I^*_m, R^*, \) and \( X^*_1, X^*_2 \). The split of total resource exports between periods 1 and 2 is then indeterminate.

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Beckerman, Wilfred (1994), "Sustainable development": is it a useful concept?*, *Environmental Values* 3 (3), 191-209.

APPENDIX 12A PROOF THAT A CHANGED INTERTEMPORAL GOAL MAY NOT CHANGE RESOURCE MANAGEMENT IN A TWO-PERIOD MODEL

The model is of a two-period, small, open, representative-agent economy with one human-made capital stock and one depletable (renewable or non-renewable) resource flow as inputs to production. It could readily be extended, although at the expense of tedious notation, to include many resources, provided that the natural growth of each resource depends only on its own stock (that is, ecosystem interactions are ignored). Let:

\[ K_t = \text{non-depreciating capital stock in period } t; i = 1 \text{ or } 2, \]

\[ I_0 = \text{domestic investment in period } 1; \]  
\[ K_0 = K_1 + I_0 \tag{12A.1} \]

\[ R_t = \text{renewable, freely extractable and storable, resource flow} \]

\[ Q(K, R) = \text{output of composite consumption/investment good; twice} \]
\[ \text{continuously differentiable, with } Q_{K,R} > 0; Q_{KK} < 0; Q_{RR} > 0; Q(K,0) = Q(0,R) = 0 \tag{12A.2} \]

\[ f = \text{foreign investment by domestic economy in period } 1 \]

\[ r = \text{world interest rate, denominated in terms of the composite} \]
\[ \text{good, and independent of } I_f \text{ because domestic economy} \]
\[ \text{is small} \]

\[ X_t = \text{export of resource (if negative, denotes import)} \]
\[ F_t = \text{world price of resource in terms of composite good;} \]
\[ \text{independent of } X_t \text{ since domestic economy is small} \]

\[ C_t = \text{consumption of composite good; hence} \]

\[ C_t = Q(K_t, R_t) - I_t - p_t X_t \tag{12A.3} \]

\[ C_t = (1 + r) F_t + p_t X_t \tag{12A.4} \]

\[ S_t = \text{given initial domestic resource stock; } G(S_t) = \text{natural} \]
\[ \text{growth of stock; all the stock is exhausted at the end} \]
\[ \text{of period } 2; \text{ hence} \]

\[ R_2 + X_2 = S_1 - R_1 - X_1 + G[S_1 - R_1 - X_1] \tag{12A.5} \]

\[ W(C_t, C_t') = \text{intertemporal welfare function; twice continuously} \]
\[ \text{differentiable, with } W_t C_t > 0 \text{ and } W_t C_t^2 < 0. \text{ Note} \]
\[ \text{that neither } R_2 \text{ nor } S_1 \text{ appear in } W, \text{ that is, the} \]
\[ \text{resource has no direct environmental value.} \tag{12A.6} \]

This whole model is an extension of Tietenberg’s (1992, pp. 30–37) textbook model of sustainability. He did not include resource trade or capital, and focused on a pure, non-renewable resource-mining economy.
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with \( Q(R) = (a - c) R_1 - b R_1^2 \), and effectively \( W'(C_1, C_2) = C_1 + C_2(1 + r) \). He still had saving at a fixed interest rate (also \( r \)). However, he did not mention that such saving must be invested in the large world outside the economy (for otherwise there must be capital in the economy). Nor did he mention the coincidence that his time preference rate in \( W'(C_1, C_2) \) is also the world interest rate \( r \), which makes the optimal amount of saving indeterminate in his model.

In the model defined by (12A.1)–(12A.6), the result to be proved is that changing the welfare function \( W(\cdot) \) makes no difference to the values of the variables \( R_1 \) and \( X_1 \) (domestic resource use, and resource trade) and \( I_D \) (domestic investment) which solve the open-economy problem:

\[
\text{Maximize} \quad W(C_1, C_2).
\]

Using (12A.1), (12A.4) and (12A.5), we have

\[
C_2 = Q(K_1 + I_D, S_1 - R_1 - X_1 + G[S_1 - R_1 - X_1] - X_2) + (1 + r) I_F + p_2 X_2,
\]

so denoting partial derivatives by subscripts, the first-order conditions for an interior solution are:

\[
\begin{align*}
\frac{\partial W}{\partial R_1} & = 0 \implies W_{C_1}Q_{R_1} = (1 + G') W_{C_2}Q_{R_2} \quad (12A.9) \\
\frac{\partial W}{\partial I_D} & = 0 \implies W_{C_1}Q_{I_D} = W_{C_2}Q_{I_D} \quad (12A.10) \\
\frac{\partial W}{\partial I_F} & = 0 \implies W_{C_1} = W_{C_2}(1 + r) \quad (12A.11) \\
\frac{\partial W}{\partial X_1} & = 0 \implies W_{C_1}p_1 = (1 + G') W_{C_2}Q_{R_2} \quad (12A.12) \\
\frac{\partial W}{\partial X_2} & = 0 \implies Q_{R_2} = p_2. \quad (12A.13)
\end{align*}
\]

Substituting (12A.11) and (12A.13) into (12A.9), (12A.10) and (12A.12) gives

\[
W_{C_1}/W_{C_2} = 1 + r = (1 + G')Q_{R_2}/Q_{R_1} = (1 + G')p_1 p_2 = Q_{R_1} \quad (12A.14)
\]

This shows that a Hotelling rule appropriate to renewable resources,

\[
p_2 = (1 + r) p_1 / (1 + G'[S_1 - R_1 - X_1]),
\]

must hold in the rest of the world if resources are to be traded in both time periods, as required for an interior solution. Obviously, if the change in welfare function is big enough, we shall move beyond an interior solution and one or more of the first-order conditions (12A.9)–(12A.13) will no longer be true.

Substituting (12A.14) into (12A.9)–(12A.13) gives the three equations

\[
\begin{align*}
Q_{R_1}(K_1, R_1) = p_1, \quad (12A.16) \\
Q_{R_2}(K_1 + I_D, S_1 - R_1 - X_1 + G[S_1 - R_1 - X_1] - X_2) = 1 + r, \quad (12A.17) \\
Q_{R_1}(K_1 + I_D, S_1 - R_1 - X_1 + G[S_1 - R_1 - X_1] - X_2) = (1 + r) p_1 (1 + G'). \quad (12A.18)
\end{align*}
\]

Because of the strict concavity conditions in (12A.2), in principle the four equations (12A.15)–(12A.18) are sufficient to determine uniquely the values of the four variables \( I_D, R_1, X_1 \) and \( X_2 \). Together \( R_1 \), \( X_1 \) and \( X_2 \) determine \( R_2 \), and hence all aspects of resource management over time \( R_1, R_2, X_1 \) and \( X_2 \). But none of (12A.15)–(12A.18) contain the welfare function \( W(\cdot) \), so we conclude that

provided the solution remains interior, a change in intertemporal welfare goal has no effect on the economy's management of its resources or its domestic capital investment.

All that will change is foreign investment \( I_F \), which is determined by (12A.11); hence total saving \( I_D + I_F \), and consumption levels \( C_1 \) and \( C_2 \), will also change.

Since sustainable development (SD) is typically defined as an inequality constraint, it cannot be incorporated into a differentiable welfare function. So let us test whether imposing the SD constraint, which is here \( C_1 \geq C_2 \), also yields the above conclusion. Consider a case where \( C_1 > C_2 \) and \( R_1 > R_2 \) in the solution to the above equation set, that is, optimal consumption and resource use are both unsustainable. Maximizing \( W(C_1, C_2) \) subject to the SD constraint \( C_1 \geq C_2 \) is then equivalent to maximizing \( C_1 \) subject to \( C_1 = C_2 \), which from (12A.8) means

\[
I_2 = (Q(K_1, R_1) - I_D - p_1 X_1 - p_2 X_2 - \frac{Q(K_1 + I_D, S_1 - R_1 - X_1 + G[S_1 - R_1 - X_1] - X_2)}{1 + r}) \quad (12A.19)
\]

hence

\[
(2 + r) C_1 = (1 + r) \frac{[Q(K_1, R_1) - I_D + p_1 X_1 + p_2 X_2 + Q(K_1 + I_D, S_1 - R_1 - X_1 + G[S_1 - R_1 - X_1] - X_2)]}{2 + r} \quad (12A.20)
\]

The first-order conditions for maximizing this \( C_1 \) with respect to \( R_1 \), \( I_D \), and \( X_1 \) and \( X_2 \) are

\[
\begin{align*}
(1 + r) Q_{R_1} &= (1 + G')Q_{R_2}, 1 + r = Q_{R_1} \\
(1 + r) p_1 &= (1 + G') Q_{R_2}, \quad p_2 = Q_{R_2}. \quad (12A.21)
\end{align*}
\]
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These are exactly equivalent to (12A.15)-(12A.18), which as already noted have at most one solution. So the SD constraint indeed does require an increase in foreign investment $I_D$ (and hence an increase in total saving also) from the level determined by (12A.13) to the level determined in (12A.19); but no change in domestic resource use $R_1$, (which will still be unsustainable), investment $I_D$, or resource exports $X_1$ and $X_2$.

However, if an economy is closed, or large and open, then the change in saving and investment caused by changing the welfare goal generally changes the interest rate path available to the economy. This then changes the path of resource management, although not necessarily to a sustainable path if the new goal is SD. In the above two-period example, if the economy is closed, then foreign investment $I_D$ and resource trade $X_1$ and $X_2$ are all zero. The economy then chooses $R_1$ and $I_D$ to maximize welfare $W(K_1, R_1) - I_D, (K_1 + I_D, S_1 - R_1)$.

A change in $W()$ then generally changes $R_1$ and $I_D$. In particular, if maximizing the old $W_1()$ results in $C_1 > C_2$, an SD constraint will shift the economy to $C_1 = C_2$. Doing this in a Pareto-efficient way requires a shift to lower $C_1$ and higher $C_2$. It will also, given the strict concavity assumptions in (12A.2) and (12A.6), entail an increase in investment $I_D$ and reductions in the interest rate $r$ and first-period resource extraction $R_1$. But we cannot say in general if resource management is sustainable ($R_1 \leq R_2$) after the shift.

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