Answer key for question 4 (second midterm)

(a) The answer I would give is that they are likely to be the same. The reason is that strong/hard sustainability requires that we bequeath natural resources in at least as good a condition as we inherited them, while weak/soft sustainability requires only that future generations be at least as well off as us. The difference depends on the extent to which other assets (produced capital, human capital, etc.) can be substituted for natural resources. If substitutability is high the difference will be large. In the case of climate change, however, I would expect that there are few opportunities to substitute other goods for climate stabilization; therefore the two forms of sustainability would be operationally equivalent.

It is possible that a student might give the opposite answer, but what counts is the reasoning. If the answer (a) correctly identifies the difference between the two forms of sustainability and (b) recognizes that the conclusion depends on the degree of substitutability between natural and other resources, it is OK. For instance, it might be argued that all the effects of climate change (rising sea levels, altered habitats etc.) could in theory be "bought off" by enough other investments (moving all structures away from inundated regions, new agricultural techniques, etc.).

(b) Total population across the three countries is 534M; 1000mt/534M = 1.87 tons per person. Multiplying by population gives

Brazil: 318mt
Germany: 154mt
US: 528mt

Current per capita US emissions are 19.87. Achieving our hypothetical target would therefore entail a 90.6% reduction: (19.87 – 1.87) / (19.87)

The target would not have immediate policy implications for Brazil, because, at 1.81 tons per capita, they are still below the equitable sustainable share of 1.87. Nevertheless, very quickly Brazil would have to make adjustments, because there is almost no room for population or economic growth that would lead to higher carbon releases. So one could say that, yes, Brazil has to adapt to the target too, just not as drastically as Germany or the US.

(c) It is not advisable to try to solve for the values of the three parameters, even though there are three equations provided. First, the relationships are multiplicative, requiring log-linearization, etc., which I am assuming few students will attempt. (A formal solution is much easier to implement in time series calculations on the same country.) More to the point, however, there is no reason to believe that the role of technology will be the same across all three countries.

A better approach is to examine the three pairwise comparisons implicit in the data. This is not particularly sophisticated, but it does provide a rough basis for assessment. These are summarized in the following table:

Countries	Population	GDP/pop	GDP	Carbon
US/Brazil	1.66	4.62	7.66	18.19
US/Germany	3.44	1.33	4.58	7.13
Germany/Brazil	0.48	3.47	1.67	2.55

Population seems to be very loosely related: Germany has more than twice Brazil's carbon emissions despite a population only about half as large. The US-to-Brazil population ratio is less than a tenth of the same countries' carbon emission ratio. On the other hand, population differences play an important role in explaining the US/Germany carbon ratio.

Affluence (GDP/pop) seems to play a significant role in the US/Brazil and Germany/Brazil comparisons,

although, taken alone, it underpredicts the US/Brazil carbon ratio and overpredicts the Germany/Brazil carbon ratio. There is only a modest difference between the US and German levels of GDP per capita, but US carbon emissions are vastly greater.

To assess technology, it is useful to consider the role of GDP, which combines population and GDP per capita. In the I = P*A*T decomposition, technology is the residual that explains everything that GDP doesn't. As we can see, very roughly, GDP differences account for between a third (US/Brazil) and two-thirds (US/Germany, Germany/Brazil) of the difference in the carbon ratio, leaving technology to explain the remainder.