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Growth, degrowth and climate change: A scenario analysis

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ABSTRACT

The paper proceeds with a discussion of the interplay of scale and intensity in determining greenhouse gas emissions. This is followed by the presentation of several macroeconomic scenarios using LowGrow, a simulation model of the Canadian economy. The scenarios considered are 'business as usual' which is a projection into the future of past trends, 'selective growth' in which differential growth rates are applied to parts of the economy according to their direct and indirect greenhouse gas emissions, and 'degrowth' where the average GDP/capita of Canadians is reduced towards a level more consistent with a world economy the size of which respects global environmental limits. The paper ends with a comparison of the scenarios.

1. Introduction

In recent years there has been a resurgence of interest in the economics of low growth, no growth and degrowth in high consumption economies.[1] This interest in low/no/de growth is based on two distinct but related considerations: the feasibility and the desirability of continuous economic growth in high consumption economies. The long-term feasibility of economic growth has been questioned by analysts, such as Ayres and Warr(2009). They emphasize the relationship between economic growth, measured as increases in real GDP, and access to cheap supplies of materials, in particular, fossil fuel sources of energy. Their prognosis is that these supplies are not expected to last far into the 21st century, undermining a fundamental condition on which past economic growth has been based. Environmental constraints on growth are also becoming more apparent (Pollard, 2010; Rockstrom et al., 2009).

Other commentators have questioned the desirability of further economic growth in high consumption economies. They question the link between wellbeing, welfare or happiness, and economic growth. It is nearly 40 years since Easterlin (1974) wrote his seminal paper challenging the assumption that economic growth improves the human lot. Now there is a burgeoning sub-discipline on the economics of happiness which received a substantial boost from Richard Layard's book *Happiness: Lessons from a New Science* (Layard, 2005). John Helliwell's analysis of international surveys of the determinants of wellbeing is another stream of work throwing light on the relationships between higher incomes and well-being. Helliwell et al.(2009) finds that "the combined effects of a few measures of the social and institutional context exceed that of income in equations explaining international differences in life satisfaction" (p. 15).

This work on resources, environment, and happiness in relation to economic growth has not gone unchallenged. The view remains widespread that a combination of new technologies, a shift from goods to services, and more reuse and recycling, will decouple economic growth from throughput, especially critical components such as fossil fuels, allowing growth to continue while resource inputs and wastes decline. It is argued that these changes will be prompted by market signals and judicious public policy so that any call for lower economic growth, let alone no growth or even worse, degrowth, are unnecessary and misguided. Similarly, the widely reported weak link between wellbeing and economic growth in high consumption economies has been called into question (Sacks et al., 2010).

Such is the nature of healthy academic debate. A number of economists (e.g. Booth, 2004; Jackson, 2009; Victor, 2008) have attempted to draw together the different strands of the debate. They argue that it would be wise to address concerns about the feasibility and desirability of continuous economic growth by taking steps to deliberately wean high consumption economies away from their dependence on economic growth. Poorer countries will themselves have to come to terms with ever more pressing local, regional and global environmental problems and possible resource shortages but this task, so it is argued, will be easier and more just if the high consumption economies take the initiative.

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[1] 'High consumption' is preferred to 'developed' on the grounds that so-called developed economies still need 'development' but of a different kind for resource, environmental and social justice reasons. While not everyone in a high consumption economy necessarily consumes at a high level because of wide and rising disparities in income and wealth, the economy is large enough for it to be possible. Likewise, there are segments of the population in developing economies that enjoy high consumption.

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One of the most important and pressing environmental constraints is the threat of catastrophic climate change about which much has been written, but too little has been done (IPCC, 2007). A reason often given for the lack of action is the concern about the threat to economic growth posed by climate change mitigation and, to a lesser extent, adaptation policies (Thorning and Illarionov, 2005). This view begs the question of whether changes in GDP are a valid measure by which to evaluate climate change impacts and policies. GDP records final expenditures but does not distinguish systematically between those that represent economic benefits and those which represent costs. Thus, a change in GDP one way or the other due to climate change, tells us little of direct significance relating to human wellbeing. More detail and different considerations are required for that purpose.

However, the fact that changes in GDP are used to assess climate change costs and policies cannot be denied. Tol (2009) provides a summary of 13 estimates of the "welfare impact of climate change expressed as an equivalent income gain or loss in percent GDP" (p. 31). Others have estimated the costs in terms of climate change mitigation and adaptation in terms of an actual reduction in GDP, expressing views such as "In an economy that is growing at 2.5% per year, a rate that is common for developed countries, spending 2.5% of GDP on climate protection each year would be equivalent to skipping one year's growth, and then resuming. Average incomes would take 29 years to double from today's level, compared to 28 years in the absence of climate costs." (Ackerman, et al., 2009, p. 5), or as Stern (2007) writes: "…one can think of annual GDP being 1% lower through time, *with the same growth rate*, after an initial adjustment" (p. 249). This allowed Stern (2007) to conclude that "an annual cost rising to 1% of GDP by 2050 poses little threat to standards of living, given that economic output in the OECD countries is likely to rise in real terms by over 200% by then, and in developing regions as a whole by 400% or more." (p. 239).

The relationship between the costs of climate change mitigation and adaptation, and the rate of economic growth depends very much on what other expenditures are displaced. The use of the additional output of the economy from 1 year to the next is fundamental in determining its rate of growth. For example, if there is a significant reduction in investment in new productive capacity because funds are diverted to unproductive climate mitigation, such as carbon capture and storage yielding no marketable output, it is implausible to assume that the rate of economic growth will be unaffected. To suggest that there will be essentially no effect on the growth rate even when climate mitigation and adaptation costs as a percentage of GDP are similar to the growth rate is unreasonable and unconvincing (Jackson, 2009, pp. 83–85).

The point here is not so much to challenge the use of changes in GDP as a measure of the costs and benefits of climate change policies or well-being in general. That has been done many times (e.g. Spash, 2007). The pursuit of economic growth remains the primary economic policy objective of most governments and it is customary to judge environmental and other policies in terms of their impact on growth. But what if a reduction in economic growth, or its elimination, even degrowth, is necessary to avoid catastrophic climate change (Weitzman, 2009)? Will this mean mass unemployment, widespread poverty, and rising government debt, as is commonly assumed? These matters are worthy of consideration while nations continue to plan and negotiate climate change strategies, and they are the topic of this paper.

The paper proceeds with a discussion of the interplay of scale and intensity in determining greenhouse gas emissions. This is followed by the presentation of several macroeconomic scenarios using LowGrow, a simulation model of the Canadian economy. The scenarios considered are 'business as usual' which is a projection into the future of past trends, 'selective growth' in which differential growth rates are applied to parts of the economy according to their direct and indirect greenhouse gas emissions, and 'degrowth' where the average GDP/capita of Canadians is reduced towards a level more consistent with a world economy the size of which respects global environmental limits. The paper ends with a comparison of the scenarios.

2. Decarbonization: Scale and Intensity

Reduced to its most basic level, any resource or environmental flow relating to an economic activity can be understood as the combination of two variables: the scale of the economic activity and the flow intensity. For example, greenhouse gas (GHG) emissions from a national economy in a year can be found by multiplying GDP per year (a measure of scale) by GHG/GDP per year (a measure of intensity), where GDP is measured in constant dollars and GHG emissions are measured in tonnes. It follows that any target for a reduction in greenhouse gas emissions must be reached by reducing a combination of scale and intensity. If the target is to be reached at some time in the future then it can be approached and met through a combination of an average annual rate of change in GDP and an average annual change in GHG intensity, recognizing that in practice the actual rates of change will vary around the averages.

Table 1 shows the average annual rate of decline in GHG intensity required to meet a target reduction in 40 years of 50% to 90% in GHG emissions, for various average annual rates of economic growth. For example, if an economy grows at 3% per year for 40 years, an average annual reduction in GHG intensity of 7.23% is required if GHG emissions are to be reduced by 80%. This compares with an average annual reduction in GHG intensity of 4.11% if there is no economic growth during that period.

While these differences in rates of decline in GHG intensity may not seem great, their implications for the absolute reduction in GHG intensity are dramatic. With no economic growth and GHG intensity declining at 4.11% per year, GHG intensity will be 20% of its initial value after 40 years. This means that for each dollar of GDP the associated emission of greenhouse gas emissions would be only 20% of its initial value 40 years hence. The changes in technology and in the composition of GDP, with more emphasis on services rather than goods, would have to be rapid and far-reaching, as would the related changes in society at large. Of course, given the global nature of the problem, relying on increasing imports of GHG intensive commodities would only give the appearance of reduced GHG intensity and would not help.

However, if the economy grows at 3% per year over the 40 year period, an average annual rate of reduction in GHG intensity of 4.11% would result in only a 36% reduction in emissions after 40 years, not 80%. Emissions would exceed the reduction target by a potentially disastrous 300%. GHG intensity must be reduced to only 6% of its initial value to achieve the target reduction of 80% in GHG emissions if the average annual rate of economic growth is 3%. If an 80% or even more ambitious target reduction in greenhouse gas emissions is to be achieved over the next 40 years, an average annual rate of economic growth of 3% will necessitate the virtual elimination of GHG emissions associated with each unit of economic activity. It will also mean fundamental shifts in many aspects of society, not just economic.

Table 1
Scale and intensity requirements for achieving greenhouse gas reduction targets.

		Rate of economic growth					
		−1%	0%	1%	2%	3%	4%
Reduction after 40 years	50%	0.73%	1.75%	2.77%	3.78%	4.80%	5.82%
	60%	1.29%	2.32%	3.34%	4.36%	5.39%	6.41%
	70%	2.03%	3.06%	4.09%	5.12%	6.15%	7.18%
	80%	3.06%	4.11%	5.15%	6.19%	7.23%	8.27%
	90%	4.87%	5.93%	6.98%	8.04%	9.10%	10.16%

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While no one can say for certain that such a sustained level of reduction in GHG intensity is impossible, it is hard to imagine how it can be accomplished without enormous changes in energy and other technologies at a pace completely unprecedented in human history. And this is only to deal with climate change. There are other pressing global environmental problems (Rockstrom et al., 2009) and resource constraints that have to be overcome faster the higher the rate of economic growth relating, for example, to energy supplies (Ayres and Warr, 2009) and critical materials (Ad-hoc Working Group on Defining Critical Raw Materials,2010). A slower rate of economic growth requires a slower and, arguably, more manageable rate of transformation of the economy and society at large, though very significant challenges will remain.[2]

3. Simulating Macroeconomic Scenarios

LowGrow is a quantitative model of the Canadian economy designed to explore different assumptions, objectives and policy measures. It is described in more detail elsewhere (Victor, 2008;Victor and Rosenbluth, 2007).[3] The simplified structure of LowGrow is shown in Fig. 1.

In LowGrow, aggregate (macro) demand is determined in the normal way as the sum of consumption expenditure (C), investment expenditure (I), government expenditure (G), and the difference between exports (X) and imports (I). Their sum total is GDP measured as total final, non-duplicated expenditure. There are separate equations for each of these components in the model, estimated with Canadian data from about 1981 to 2005 depending on the variable. Production in the economy is estimated by a Cobb–Douglas production function in which macro supply is a function of employed labor (L) and employed capital (K). The time variable (t) represents changes in productivity from improvements in technology, labor skills and organization. The production function is shown as macro supply at the bottom of Fig. 1. It estimates the labor (L) and employed capital (K) required to produce GDP allowing for changes in productivity over time.[4]

There is a second important link between aggregate demand and the production function. Investment expenditures (net of depreciation) which are part of aggregate demand, add to the economy's stock of capital increasing its productive capacity. As capital and labor become more productive over time, which has been typical in Canada, aggregate demand must increase to avoid an increase in unemployment. Economic growth (i.e. increases in GDP) would seem to be needed to prevent unemployment rising as productive capacity increases.

Population is determined exogenously in LowGrow, which offers a choice of three projections from Statistics Canada. Population is also

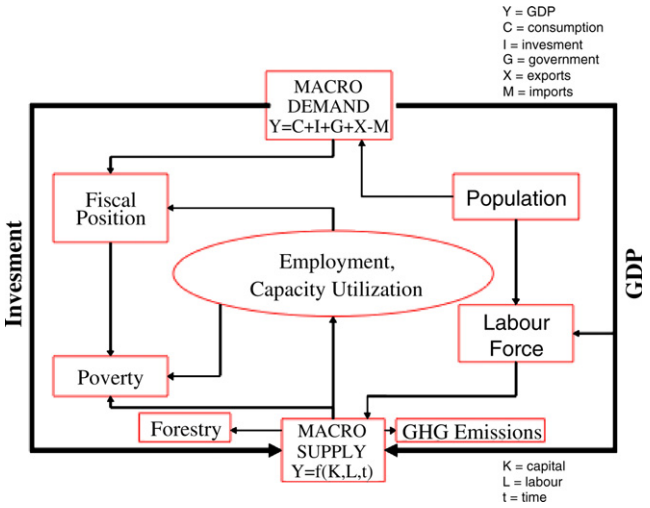

Fig. 1. The simplified structure of LowGrow.

one of the variables that determines consumption expenditures in the economy. The labor force is estimated in LowGrow as a function of GDP and population.

LowGrow includes an exogenously determined rate of interest that remains unchanged throughout each simulation. A higher cost of borrowing discourages investment, which reduces aggregate demand. It also raises the cost to the government of servicing its debt. The price level is not included as a variable in LowGrow although the model warns of inflationary pressures when the rate of unemployment falls below 4% (i.e. effectively full employment in Canada).

LowGrow includes features that are particularly relevant for exploring a low, no and degrowth economy. LowGrow includes emissions of carbon dioxide and other greenhouse gasses, a carbon tax, a forestry sub-model, provision for redistributing incomes, and a measure of poverty using the UN's Human Poverty Index (i.e. HPI-2 for selected OECD countries). LowGrow allows additional funds to be spent on health care and on programs for reducing adult illiteracy (both included in HPI-2) and estimates their impacts on longevity and adult literacy using equations from the literature.

Implications of changes in the level of government expenditures can be simulated in LowGrow through a variety of fiscal policies including: an annual percentage change in government expenditure that can vary over time, and a balanced budget. LowGrow keeps track of the overall fiscal position of all three levels of government combined (federal, provincial, and municipal) by calculating total revenues and expenditures (including those for poverty reduction) and estimating debt repayment based on the historical record. As the level of government indebtedness declines the rates of taxes on personal incomes and profits in LowGrow are reduced endogenously, which is broadly consistent with government policy in Canada.

In LowGrow, as in the economy that it represents, economic growth is driven by: net investment which adds to productive assets, growth in the labor force, increases in productivity, an increase in the net trade balance, growth in government expenditures and growth in population. Low, no and degrowth scenarios can be examined by reducing the rates of increase in each of these factors singly or in combination.

4. Scenario 1: 'Business as Usual'

It is convenient to start analyzing low, no and degrowth scenarios by establishing a base case with no new policy interventions. This is the 'business as usual' case illustrated in Fig. 2.

[2] To see whether faster rates of economic growth are required for faster reductions in intensities Victor examined data for high income countries. "Broadly speaking, in the 30 years from 1972 to 2002 *slower* rates of economic growth in high income countries were associated with *greater* reductions in CO2 intensity and *greater* reductions in energy intensity." (Victor, 2008 op cit, pp.120–122).

[3] Victor and Rosenbluth (2007) is based on LowGrow version 1.0. Victor (2008) uses LowGrow version 2.0. The main difference between the versions is in the way employment is determined. All differences are described on line in LowGrow version 2.0 which can be downloaded at www.managingwithoutgrowth.com.

[4] The only inputs in the production function used in LowGrow are labor and capital. The Cobb–Douglas formulation assumes that they are substitutes for each other and that both are essential for production. As expressed, the production function does not include other inputs such as materials and energy, the scarcity of which may impose limits on economic growth. In LowGrow these other inputs are treated as a derived demand, determined, in the case of energy, by GDP and price. This limitation is not critical since the main purpose of the production function in LowGrow is to estimate employment associated with final demand and not to investigate the implications for economic growth of resource scarcities.

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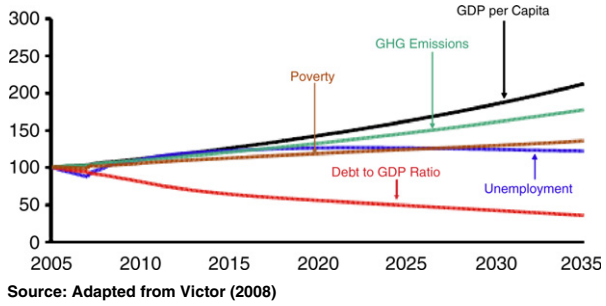

Fig. 2. Scenario 1 — 'Business as usual'.

In the business as usual scenario, based on conditions prevailing in 2005, real GDP per capita more than doubles between the start of 2005 and 2035, and greenhouse gas emissions increase by nearly 80%, which is slightly less than GDP/capita due to projected reductions in intensity. The unemployment rate rises then falls ending about 20% above its starting value, the ratio of government debt to GDP declines by nearly 40% as Canadian governments run budget surpluses, and the Human Poverty Index rises, due to the projected increase in the absolute number of unemployed people.

The business as usual scenario, which was formulated just ahead of the onset of the recession of 2008/09, is not a prediction of the Canadian economy. It is used as a benchmark based on past trends against which alternative scenarios can be compared. Although business as usual represents an unlikely future, the scenario retains some policy relevance even after the recession since the principal economic policy objective of the Canadian government, as in other high consumption economies, is to get back 'on track' with regard to economic growth.

5. Scenario 2: A Low/No Growth Scenario

A wide range of low and no growth scenarios can be examined with LowGrow. Fig. 3 shows one example. Compared with the business as usual scenario, starting in 2010 GDP per capita grows more slowly, leveling off around 2028 at which time the rate of unemployment is 4.8%. The unemployment rate continues to decline to 4.0% by 2035. By 2020 the poverty index declines from 10.7 to an internationally unprecedented level of 4.9, and the debt to GDP ratio declines to about 45%. Greenhouse gas emissions are 22% lower in 2035 than 2005 and 32% lower than their high point in 2010.

These outcomes are obtained by slower growth in government expenditure, net investment and productivity, a modest but positive net trade balance, cessation of growth in population, a reduced average work year, a revenue neutral carbon tax, and increased government expenditure on anti-poverty programs, adult literacy programs and health care. Policies for bringing about these changes are discussed in Victor (2008, chapter 11).

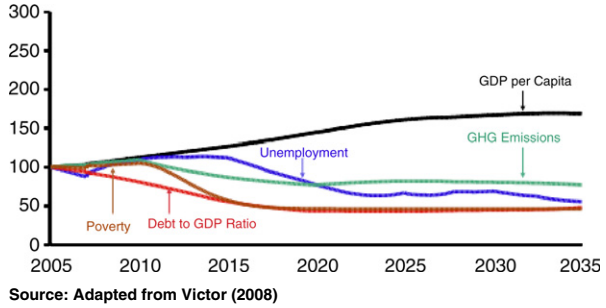

Fig. 3. Scenario 2 — A low/no growth scenario.

6. Scenario 3: Selective Growth

In an economy exhibiting no growth of total output, as measured by real GDP, it is still possible and desirable, for some sectors, products and services to grow, while others remain stable and yet others decline. Such would be the pattern of development in an economy in which renewable energy replaces energy from fossil fuels, with or without continued growth in GDP. The wide diversity of resource and environmental impacts associated with individual components of GDP and the processes for making and distributing them, raise the possibility that economic growth can continue indefinitely provided it is concentrated in activities that have the lowest impacts. Jonathan Harris has suggested this possibility as a way of achieving "environmentally beneficial economic expansion" with specific reference to climate change. Harris(2009) decomposes the basic macroeconomic aggregates of consumption, investment, and government expenditure into sub-categories according to their environmental impact, separating "macroeconomic aggregates that we wish to limit, and those that we wish to encourage" (p. 12). According to Harris (2009), the latter includes: consumption of human-capital intensive services, household investment in consumer durables, investment in energy-conserving manufactured capital, investment in natural capital, investment in human capital services, government consumption of human capital-intensive services, government investment in energy-conserving manufactured capital, and government investment in natural capital government investment in human capital, all of which "can grow over time without significant environmental impact, and indeed have a positive effect in the case of natural capital or energy-conserving investment" (p. 11). Harris (2009) recognizes that "not all services are environmentally benign…and that this formulation also assumes that investment in natural capital is wisely managed" (p. 12), but with these caveats, he concludes that as long as growth is concentrated in these sectors, it can continue indefinitely.

As with much of the debate about economic growth, the question of time scale is very important. In this case, how much breathing room does selective growth offer to high consumption economies trying to meet ambitious greenhouse gas reduction targets? This is an empirical question. The approach taken here to investigate it involved the following steps:

1. Estimates of direct and indirect data greenhouse gas emissions per dollar of final demand for each of 101 categories of commodity were obtained from Canadian input–output data for 2005.[5]
2. Commodities were grouped into two categories: 'high intensity' and 'low intensity'.
3. A rate of growth for the entire economy was selected (i.e. the sum of expenditures on high intensity and low intensity commodities).
4. A target percent reduction level of expenditure on high intensity commodities was set for 2020.
5. The growth path and greenhouse gas emissions consistent with these assumptions were simulated with LowGrow.

The logic is simple. The specification of any rate of economic growth and any target level of expenditure on high intensity commodities determine the growth in expenditure on low intensity commodities and the total level of greenhouse gas emissions over time as illustrated in Fig. 4.

In this scenario, GDP/capita grows at the same rate as in the business as usual scenario (Fig. 2). Expenditure on high intensity commodities is reduced to 0% of GDP by 2020. This is an extreme assumption, but is used to simulate the maximum contribution that a switch to low intensity commodities could make to the reduction of greenhouse gas emissions assuming no reduction in the overall rate of economic growth.

[5] Provided on request from Statistics Canada.

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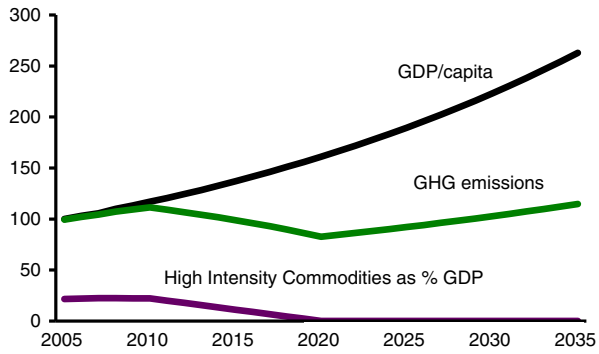

Fig. 4. Scenario 3 — A selective growth scenario.

As shown in Fig. 4, under these assumptions, greenhouse gas emissions decline until 2020 and then start rising again so that by 2035 they are 15% higher than in 2005.

There are several reasons for this disappointing result. First, the groups of high intensity and low intensity commodities, as defined in this simulation, only differ by a factor of four in terms of their greenhouse gas intensities. This means that as expenditure is switched from high to low intensity commodities, direct and indirect greenhouse gas emissions decline by 60% until no further substitution is possible. With further economic growth beyond that they begin to rise.

Second, expenditure on high intensity commodities represented only 22% of final demand in Canada in 2005. Hence, the potential gains from switching to low intensity commodities is limited in that 78% of final demand was already being spent on them.

While the distinction between high and low intensity commodities is somewhat arbitrary, there is an important relationship between the greenhouse gas intensities used to distinguish high and low intensity commodities and the relative sizes of these categories in final demand. The higher the relative intensities between high and low intensity commodities the smaller is the proportion of final demand falling into the low intensity category and vice versa. If high intensity commodities are a small proportion of total GDP then the potential for substituting low intensity commodities for them is small as well. The four to one ratio used for the simulation shown in Fig. 4 arose from a rather sharp break in the intensities as revealed by the data. That this ratio is not larger is due to the fact that final demand expenditures on low intensity commodities give rise to intermediate expenditures on high intensity commodities that are used in their production. This shows up, for example, in the use of fossil fuels to produce services. A sensitivity analysis was undertaken in which the greenhouse gas intensities of high and low intensity commodities were assumed to differ by a factor of 10 rather than 4 and expenditure on low intensity commodities was to fall to 10% of GDP by 2020. In this scenario total greenhouse gas emissions decline to 2020 and then increase back to their 2005 level by 2035; better but still unsatisfactory.

Selective growth does offer some potential for mitigating the economic impacts of reductions in greenhouse gas emissions, but, it would appear, it is modest and short term. It is even more modest than these greenhouse gas scenarios suggest once additional resource and environmental concerns are factored in. Some commodities that have low greenhouse gas intensities have high intensities with respect to other issues. Taking this into account further limits the scope for substituting low intensity commodities for high intensity commodities. For example, expenditure commodities with a high 'carbon footprint' (i.e. high direct and indirect carbon emissions) accounted for 22% of UK final demand in 2000. At the same time, expenditure on high real land footprint commodities (i.e. based on the ecological footprint excluding the carbon component) accounted for 20% of UK final demand (based on data in Wiedmann et al., 2006). The percentage of UK final demand represented by commodities that were low intensity in both carbon and real land footprint was only 15% of UK final demand, offering reduced potential for selective growth to combine lower environmental impacts with continued economic growth.

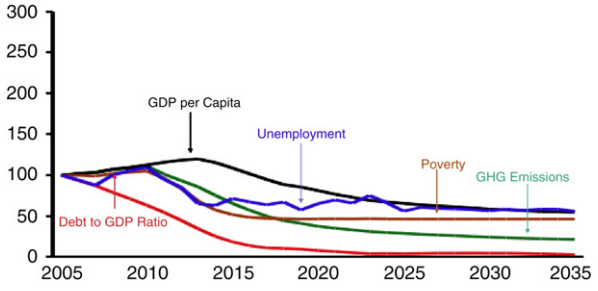

Fig. 5. Scenario 4 — A degrowth scenario.

7. Scenario 4: Degrowth

Schneider et al. (2010) define sustainable de-growth as "an equitable downscaling of production and consumption that increases human well-being and enhances ecological conditions at the local and global level, in the short and long term." They go on to say that: "Sustainable degrowth will involve a decrease in GDP as currently measured, because of a reduction in the large-scale, resource-intensive productive and consumptive activities that constitute a big portion of GDP. However, what happens to GDP is of secondary importance; the goal is the pursuit of well-being, ecological sustainability and social equity… GDP can go down and nevertheless other dimensions of life can improve" (Schneider et al., 2010 p. 512).

LowGrow can be used to generate degrowth scenarios. One such scenario for Canada is described in this section. Obviously, it is not intended that degrowth continue indefinitely; rather that it is a transformative path leading to a steady-state at a reduced level of economic output. This steady-state could be defined by a reduced level of material and energy throughput.[6] For present purposes this reduced level of economic output is defined in terms of GDP and GDP per capita, which amount to the same when population is constant as assumed here. The following assumptions were made to develop a target level of GDP per capita for a Canadian degrowth scenario to be reached by 2035 (consistent with the other scenarios already presented), based on Canada's fair share of global ecosystem capacity as measured by the ecological footprint:

- The global ecological footprint began to exceed global biocapacity in 1980 (Ewing et al., 2010)[7] suggesting that world GDP in 1980 of US$ 17.6 trillion (in constant 2000 US dollars, World Bank (2010)) was at a sustainable level.
- In 1980, carbon accounted for 40% of the global ecological footprint. If global carbon emissions were reduced by 40% by 2035 compared to 1980 then this would allow world GDP to be at a level reached in 1999 (US$ 30.5 trillion) without exceeding global biocapacity.
- to derive a sustainable average global GDP/capita it was necessary to divide the 1999 world GDP by global population. 8 million was chosen, which is the low variant of the UN world population projections. (Anonymous, 2009) This gives an average global sustainable level of GDP/capita of $3815, which is approximately one tenth of Canada's GDP/capita in 2010.

[6] See Victor (2009) for alternative definitions of a steady-state economy.
[7] The year in which this occurred has changed slightly as the estimates of the ecological footprint has been updated.

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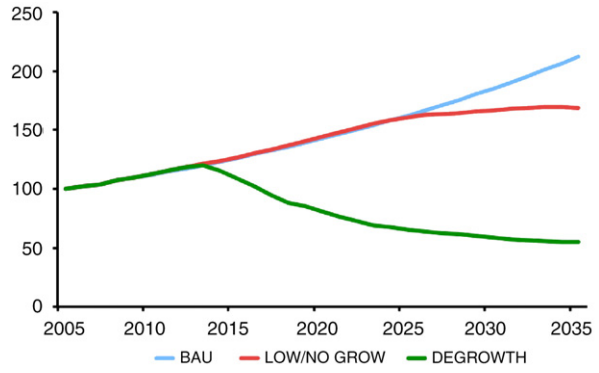

Fig. 6. GDP/capita.

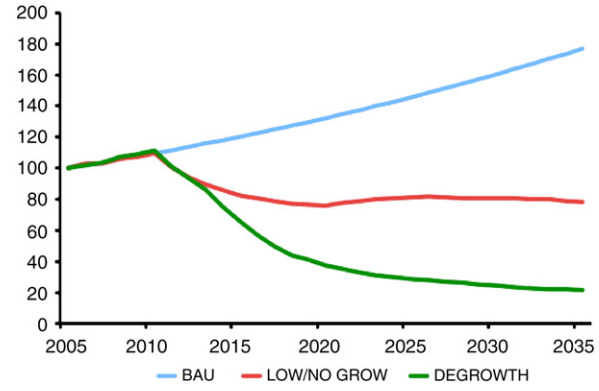

Fig. 7. Greenhouse gas emissions.

– Rather than use a per capita GDP of $3815 as the 2035 target for a degrowth scenario, a more modest interim degrowth objective of $15,260 per Canadian was adopted, which can be regarded as a step along the way towards a more equal share for Canadians of global economic output. To put this level of GDP/capita in context, it is the level enjoyed on average by Canadians in 1976.

Fig. 5 shows a Canadian degrowth scenario that achieves the target reduction in GDP/capita ($15,260) by 2035 as well as several important social and environmental objectives as well.

In this degrowth scenario, compared with 2005, there are very substantial reductions in unemployment, the human poverty index and the debt to GDP ratio. Greenhouse gas emissions are reduced by nearly 80%. This reduction results from the decline in GDP and a very substantial carbon tax.

8. Conclusion: Three Scenarios Compared

The scenarios presented above are not to be understood as predictions. They are internally consistent macroeconomic projections based on a combination of historical data, behavioral relationships, and assumptions about future changes and possibilities. The scenarios are designed to improve understanding of the range and character of alternative paths from which a choice will have to be made. Many other interesting scenarios are also possible and further work on developing them needs to be done: scenarios for more countries and with more detail in several dimensions including sectoral, regional, financial, ecological, distributional and social. Nonetheless, much can be learned even from these few widely different and preliminary scenarios by comparing them as is done in the following figures. Figs. 6–8 compare various assumptions and

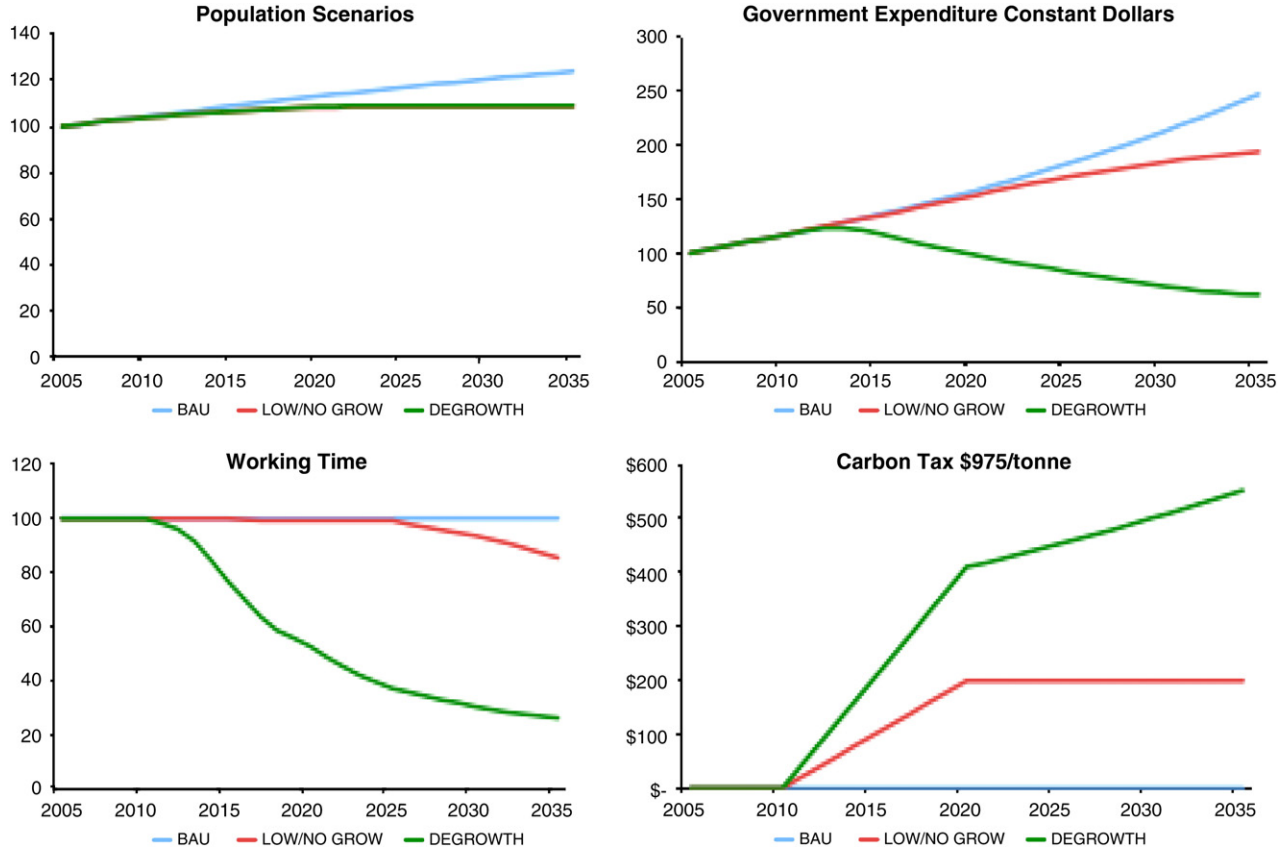

Fig. 8. Scenario drivers.

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results from the business as usual, no/low growth and degrowth scenarios (i.e. scenarios 1, 2 and 4).

Fig. 6 shows that GDP/capita in the low/no growth scenario levels off at about 80% of the level it reaches in the'business as usual' scenario, while in the degrowth scenario GDP/capita falls to 26% of the business as usual scenario by 2035.

Fig. 7 shows greenhouse gas emissions continue to rise in the business as usual scenario, exceeding the 2005 level by 77% in 2035. In the low/no growth scenario they are 56% less than the business as usual scenario in 2035, and 22% less than in 2005. In the degrowth scenario greenhouse gas emissions are 88% less than in the business as usual level in 2035 and 78% below the 2005 level.

Fig. 8 compares several exogenous drivers of the scenarios: population, government expenditure, working time and the carbon tax rate. In the business as usual scenario it is assumed that the Canadian population continues to grow throughout the 2005–2035 period while in the two other scenarios population is assumed to level off as a result of a lower fertility rate and reduced immigration. Government expenditure continues to rise in the business as usual scenario and in the low/no growth scenario, though less so in the latter. In the degrowth scenario, government expenditure declines to only 25% of its value in 2035 in the business as usual scenario. In the business as usual scenario the average annual work year of employed Canadians remains constant. It declines 15% by 2035 in the low/no growth scenario and by 75% in the degrowth scenario. Finally, Fig. 8 shows no carbon tax in the business as usual scenario, a carbon tax that increase to $200/tonne of carbon (in 1997 constant dollars) in the low/no growth scenario and one that continues rising in the degrowth scenario to $550/tonne of carbon.

By comparing the scenarios in this way it is easy to see that the differences between the low/no growth scenario and the business as usual scenario are far less dramatic than those between these two scenarios and the degrowth scenario. This finding highlights the significance of the level at which any high consumption economy stabilizes, something that should be made more explicit by those who advocate a steady-state economy and degrowth. No doubt it will be as more work is done on scenario analysis along the lines described in this paper.

References

Ackerman, F., Stanton, E.A., DeCanio, S.J., Goodstein, E., Howarth, R.B., Norgaard, R.B., Norman, C.S., Sheeran, K.A., 2009. The economics of 350: the benefits and costs of climate stabilization. Economics for Equity and Environment. http://www.e3network.org/papers/Economics_of_350.pdf.

Ad-hoc Working Group on Defining Critical Raw Materials, 2010. Critical Raw Materials for the EU. June.

Anonymous, 2009. World Population Prospects: The 2008 Revision. http://esa.un.org/UNPP/2009.

Ayres, R.U., Warr, B., 2009. The Economic Growth Engine: How Energy and Work Drive Material Prosperity, Edward Elgar. Cheltenham, Northampton,MA.

Booth, D.E., 2004. Hooked on Growth: Economic Addictions and the Environment. Rowman & Littlefield, Lanham.

Easterlin, R., 1974. Does economic growth improve the human lot? In: Reder, D.P., Reder, M.W. (Eds.), Nations and Households in Economic Growth: Essays in Honor of Moses Abramovitz. Academic Press, New York, pp. 89–125.

Ewing, B., Moore, D., Goldfinger, S., Oursler, A., Reed, A., Wackernagel, M., 2010. The Ecological Footprint Atlas 2010. Global Footprint Network. http://www.footprintnetwork.org/images/uploads/Ecological%20Footprint%20Atlas%202010.pdf2010.

Harris, J.M., 2009. Ecological macroeconomics: consumption, investment, and climate change. Real-World Economics Review 50, 34–48.

Helliwell, J., Barrington-Leigh, C.P., Harris, A., Huang, H., 2009. International evidence on the social context of well-being. NBER Working Paper, p. 14720 http://www.nber.org/papers/w14720.

IPCC, 2007. Climate change 2007: synthesis report. Summary for Policymakers.

Jackson, T., 2009. Prosperity without Growth: Economics for a Finite Planet, Earthscan. Sterling, VA, London.

Layard, R., 2005. Happiness: Lessons from a New Science. Allen Lane, London.

Living Planet Report 2010. In: Pollard, D. (Ed.), Biodiversity, Biocapacity and Development.

Rockstrom, J., et al., 2009. Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14 (2) September.

Sacks, D.W., Stevenson, B., Wolfers, J., 2010. Subjective Well-Being, Income, Economic Development and Growth. http://siteresources.worldbank.org/DEC/Resources/84797-1251813753820/6415739-1251815804823/Justin_Wolfers_paper.pdf.

Schneider, F., Kallis, G., Martinez-Alier, J., 2010. Crisis or opportunity? Economic degrowth for social equity and ecological sustainability. Introduction to this special issue. Journal of Clean Production. 18, 511–518.

Spash, C.L., 2007. The economics of climate change impacts a la Stern: novel and nuanced or rhetorically challenged? Ecological Economics 63, 706–713.

Stern, N.H., Great Britain. Treasury, 2007. The Economics of Climate Change: The Stern Review. Cambridge University Press, Cambridge, UK; New York.

Climate Change and Economic Growth: A Way Forward to Ensure Both. In: Thorning, M., Illarionov, A. (Eds.), International Council for Capital Formation and the Institute of Economic Analysis.

Tol, R., 2009. The economic effects of climate change. Journal of Economic Perspectives 23 (2), 29–51.

Victor, P.A., 2008. Managing without growth. Slower by Design, Not Disaster. Edward Elgar, Cheltenham, U.K.–Northampton, MA, USA.

Victor, P.A., 2009. Herman Daly and the steady-state economy, in The Encyclopedia of Earth. http://www.eoearth.org/article/Herman_Daly_Festschrift:_Herman_Daly_and_the_Steady_State_Economy2009.

Victor, P.A., Rosenbluth, G., 2007. Managing without growth. Ecological Economics 61, 492–504.

Weitzman, M.L., 2009. On modeling and interpreting the economics of catastrophic climate change February The Review of Economics and Statistics, XCI 1, 1–19.

Wiedmann, T., Minx, J., Barrett, J., Wackernagel, M., 2006. Allocating ecological footprints to final consumption categories with input–output analysis. Ecological Economics 56, 28–48.

World Bank, 2010. World Development Indicators On Line, World Bank. http://data.worldbank.org/data-catalog/world-development-indicators.

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