



Resilient and Inclusive Prosperity within Planetary Boundaries

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Abstract

The current model of economic growth generated unprecedented increases in human wealth and prosperity during the 19th and 20th centuries. The main mechanisms have been the rapid pace of technological and social innovation, human capital accumulation, and the conversion of resources and natural capital into more valuable forms of produced capital. However, there is evidence emerging that this model may be approaching environmental limits and planetary boundaries, and that the conversion of natural capital needs to slow down rapidly and then be reversed. Some commentators have asserted that in order for this to occur, we will need to stop growing altogether and, instead, seek prosperity without growth. Others argue that environmental concerns are low-priority luxuries to be contemplated once global growth has properly returned to levels observed prior to the 2008 financial crisis. A third group argues that there is no trade-off, and, instead, promotes green growth: the (politically appealing) idea is that we can simultaneously grow and address our environmental problems. This paper provides a critical perspective on this debate and suggests that a substantial research agenda is required to come to grips with these challenges. One place to start is with the relevant metrics: measures of per-capita wealth, and, eventually, quantitative measures of prosperity, alongside a dashboard of other sustainability indicators. A public and political focus on wealth (a stock), and its annual changes, could realistically complement the current focus on market-based gross output as measured by GDP (a flow). This could have important policy implications, but deeper changes to governance and business models will be required.

Key words: green growth, limits to growth, planetary boundaries, resilience, sustainable prosperity
JEL codes: O10, Q01, Q5

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I. Introduction

The current model of economic growth generated unprecedented increases in human wealth and prosperity during the 19th and 20th centuries (Deaton, 2013). The main drivers of growth have been the rapid pace of technological and social innovation, human capital accumulation, and the conversion of resources and natural capital into more valuable forms of produced capital (McLaughlin *et al.*, 2014). Ecological economists have also argued that the availability of exergy (energy that can do work) has been a key factor (Ayres and Warr, 2009).

Irrespective of the precise mechanisms and their relative importance, there is no doubt that the model of industrial development pursued initially by Europe, then the rest of the developed world, and, most spectacularly, in recent times by Asia and China, has been phenomenally successful in increasing prosperity. Development and increased wealth in China alone has had a remarkable impact on reducing global poverty. While much remains to be done to raise living standards around the world, the progress of recent decades is to be applauded.

However, all is not well with the economic systems predominating around the world. This has become increasingly clear, with the large numbers of people in various locations across the globe expressing their dissatisfaction in different ways, reflected by the emergence of green political parties in various countries, the Arab Spring, the Occupy movement, and the recent phenomenon of *Capital in the Twenty First Century* (Piketty, 2014).

Problems are emerging in three important and related ways. The predominant global economic growth model: (i) is environmentally unsustainable; (ii) produces increasingly unequal outcomes; and (iii) is not resilient to shocks, as demonstrated by the 2008 financial crisis.

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There are multiple causes of these three problems. One important factor is that economic policy-making continues to play these issues down relative to other challenges. This is illustrated by the fact that the rate of change of short-run, aggregate, market-based output, generally measured by GDP, continues to dominate economic and political discourse. This is for understandable reasons: declines in production lead to idle enterprises and unemployed people today, and this has great political significance (Coyle, 2014). However, GDP growth does not focus attention on these three core aspects of sustainable prosperity: it does not capture environmental externalities (because it is market-based), nor distributional considerations (because it is an aggregate measure), nor does it provide any signal of systemic risk (because it is the quarterly rate of change of a spot flow-based measure). To tackle the three major challenges of our current economic system, different measures are required, capturing different objectives.

One measure that deserves greater attention from economic policy-makers is the stock and distribution of wealth in the economy (Hamilton and Hepburn, 2014). Wealth is defined as the stock of assets that can generate future income and well-being. It is, by definition, forward-looking. It is also more closely related to prosperity than GDP. As is well known, for instance, GDP can be increased by pollution and its (partial) clean up, even though this may harm vulnerable people. It is also possible to boost current GDP by running down current wealth: rapidly exhausting renewable resources such as fish stocks provide a good example. Yet there is nothing sacrosanct about GDP. The focus on GDP is actually a relatively recent phenomenon, following the success of Keynesian economics in emphasizing the importance of short-run demand management (Hicks, 1942). One century ago, statisticians such as Giffen (1889) were as much concerned with stocks of capital as with flows of output and income.

For the time being, however, GDP growth retains its dominant place in the discourse, and most of the discussion about the transition to a more sustainably prosperous world is discussed in terms of its impact on growth. Do we need to put a halt to economic growth to sustain prosperity? Some commentators have asserted that this is necessary to address three categories of problems relating to the natural environment, inequality and resilience (Jackson, 2009; Dietz and O'Neill, 2013). Others argue the opposite: environmental concerns are low-priority luxuries to be contemplated once global growth has returned to levels observed prior to the 2008 financial crisis. A third group, including many governments and international institutions, argue that there is no trade-off. Instead, they promote *green growth*: the (politically appealing) idea that the economy can grow

while environmental problems are addressed (OECD, 2011; IMF, 2012; World Bank, 2012; ADBI/ADB, 2013; GGGI, 2014). However, proponents of this view would admit that the nature and structure of economic growth need to change, and there has been some attempt to define how this might occur (Hepburn and Bowen, 2013; Baptist and Hepburn, 2014).

If GDP growth is not the primary objective, these debates are not of central importance. As noted above, wealth is arguably a more useful metric. Ultimately, some measure of shared prosperity, and an economy's ability to sustain it, is what matters. But how should prosperity be defined? Could an aggregate measure of national prosperity be developed that was genuinely useful for policy-makers? Definitional and measurement problems abound. For example, if prosperity is defined as "access to solutions to human problems" (Hanauer and Beinhocker, 2014, p. 42), how should "solutions" be defined and measured? In addition, the development of some solutions (e.g. vaccines against infectious diseases) may generate more prosperity than others (e.g. biochemical weapons). In constructing a measure of national wealth or prosperity, what is the right balance between conceptual accuracy on the one hand, and feasibility and ease of data collection and aggregation on the other?

These are enormous questions for China and the world economy: indeed, they are some of the most important within the social sciences. Even still, these issues merely scratch the surface of the intellectual terrain that needs to be explored in the coming decade. The present paper does not provide answers to these questions, but, rather, the objective of this paper is to sketch out an agenda for scholarship and to provide pointers for future research. With this objective in mind, the paper is structured as follows. Section II considers the challenge of environmental sustainability: of achieving a model of prosperity within planetary boundaries. Section III briefly reviews the challenges created by growing inequality at the national level. Section IV briefly considers the resilience of our economic systems, viewed as complex reflexive systems. Section V concludes with a sketch of the sort of thinking, analysis, data and modeling required to advance scholarship on these questions.

II. Prosperity within Planetary Boundaries?

Are we running out of energy or materials to power our economies? In a now famous bet in 1980, biologist Paul Ehrlich bet economist Julian Simon that the price of five commodities (copper, chromium, nickel, tin and tungsten) would rise in real terms by

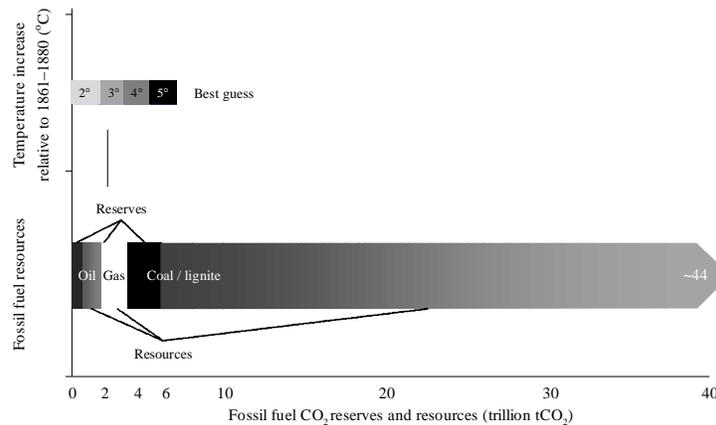
1990. They both “bought” US\$200 of each of the five commodities (total US\$1000) at prevailing prices on 29 September 1980. Simon would pay Ehrlich if prices increased, and vice versa. The real prices of the basket of commodities actually fell from US\$1000 to US\$424, despite growth in the global population of 800 million, so Ehrlich lost the bet, and paid Simon US\$576.

While the bet in itself did not prove much, it does seem unlikely that material and energy constraints will be the ultimate challenge for humanity. Total global energy consumption was approximately 500 exajoules (EJ) in 2010. There are 40 000 EJ in known fossil fuels reserves: approximately 80 years at current rates of consumption. More importantly, the solar energy striking Earth amounts to approximately 5 500 000 EJ each year. In other words, if all of the solar energy could be captured and converted to useable form, 1 hour of solar energy could power the entire global economy for a year. Capturing all that energy will never be feasible; however, the sheer scale of the resource suggests that as the cost of solar cells continues to decline, partly through support from government for R&D and deployment, our energy challenges are likely to be surmountable. This is not to mention energy from other sources, from other renewables, such as wind and hydro, to nuclear fission or fusion. It is true, however, that solutions will require technological progress: if every human on Earth had the ecological footprint of the typical North American or Western European, by some calculations the amount of biologically productive land and sea area required at current technologies would exceed that available by three to fivefold; it is claimed that we would need three to five “Earths” to sustain us (Rees, 1992; van den Bergh and Verbruggen, 1999; Fiala, 2008).

There is, however, a much more serious and urgent set of planetary boundaries. In contrast to fossil fuels and material commodities, many renewable resources, such as biodiverse ecosystems or a stable climate, do not have a price. Without prices, there is less incentive to conserve these renewable resources and for technologies to emerge that provides alternatives and substitutes for meeting the underlying human needs.

Many renewable resources are threatened. In what is now often referred to as the Anthropocene (an era named because human activity is currently a dominant force on Earth), scientists are working on identifying a set of so-called “planetary boundaries” (i.e. safe distances from dangerous thresholds) that we should avoid crossing (Rockström *et al.*, 2009). For instance, humans now extract over three times the “safe” level of nitrogen from the atmosphere, largely for agricultural use. This ends up polluting waterways and coastlines, accumulating on land, or being emitted back to the atmosphere as nitrous oxide,

Figure 1. Atmospheric Capacity versus Fossil Fuel Reserves



Source: Produced by Alexander Otto based on data and calculations from Aurora Energy Research (2014).

a powerful greenhouse gas that causes global warming. Climate change represents another planetary boundary. As Figure 1 shows, only a small fraction of the carbon dioxide in total fossil fuels reserves can be released into the atmosphere if we are to have a reasonable probability of keeping temperature increases on Earth below 2°C without taking other drastic measures.

Biodiversity loss is a third boundary that we are at risk of crossing (Rockström *et al.*, 2009; Helm and Hepburn, 2014). The fossil record shows an extinction rate of 0.1 to 1 per million species every year. The current rate of extinctions is estimated to be 100 to 1000 times higher, largely as a result of human activity. This also matters economically. For instance, if bees were to be wiped out, enormous sums of money would need to be spent on manual pollination within agriculture for our food systems to continue to function.

Will these planetary boundaries, rather than material or energy constraints, limit economic growth? The answer will depend upon how quickly and effectively we can transform current consumption and production trends, substitute for natural resource use and protect ecosystem functions. Innovation in technology and social systems is required, and polluters must pay for the consequences of their actions, among other things. If appropriate institutions can be established to protect critical commons and open-pool resources, whether economic growth (measured in the value of the goods and services provided) is limited will depend largely upon whether technological and social innovation can keep up with increasing per capita demands and increasing

populations.

The social scientific analysis required to support this research agenda should start from the perspective that the Earth's environment and ecosystems, including the climate system, are complex (Rind, 1999). Our experience with weather forecasts attests that it is very difficult to predict what will emerge from the trillions of interactions among molecules in the atmosphere, oceans, and on land. The climate can be understood roughly as 30-year average weather. Modeling climate interactions therefore requires long timelines and vast computing power (Palmer, 2011).¹ At best, such models can produce imperfect probability estimates of potential outcomes.²

As human impacts on natural ecosystems increase, such ecosystems move further from historical conditions. As this continues, the data series and information sets that underpin our ability to understand and predict such systems become less reliable. As the relevant domain incorporates more “unknown unknowns,” so too does the risk of tripping some kind of threshold that could send the system into catastrophe.

III. Inequality and Sustainable Prosperity

The distribution of wealth and prosperity within and between countries has changed rapidly in recent years, leading to, for instance, the “Occupy” movement and the slogan “We are the 99%” (Alvaredo *et al.*, 2013; Mankiw, 2013), and the current enormous popular interest in the economics of wealth inequality (Piketty, 2014). Wealth inequality in the USA increased sharply between 2007 and 2010 (Wolff, 2012). Extraordinarily, median wealth fell by 47 percent over that period as asset prices plummeted.³

Inequality can be seen as a threat to sustainable prosperity for several reasons. First, for any standard social welfare function, for any societal level of prosperity, how widely

¹Climate forecasting is both easier and harder than weather forecasting. On the one hand, it is much easier to predict the long-run average of a variable than an individual draw: the long-run average of the weather in a given location is easier to predict than the specific weather on a particular date in the future. On the other hand, much greater computing power is required over much longer time scales to predict the climate; over 30 years, the climate system will be subjected to many more shocks and larger external “forcings” than is possible over, say, 5 days.

²Frame and Stone (2012) make the claim that the 1990 IPCC forecasts of warming have turned out to be “roughly right” once various surprise events are factored into account.

³See Section IV below on the relevance of stability to sustainable prosperity.

individual levels of prosperity are shared is important. Second, a social system is unlikely to be stable in the long run if wealth is concentrated in the hands of a small elite. Third, Ostry *et al.* (2014) conclude that lower net inequality is correlated with more rapid and durable growth. This follows other evidence that inequality may slow conventional economic growth.⁴ Fourth, it may be that the consumption habits of the very rich are less sustainable than those with average wealth; if so, inequality increases environmental pressures.

There are several relevant stylized facts about wealth inequality. First, the very rich have become richer (Piketty and Saez, 2003; Atkinson and Piketty, 2010; Piketty, 2014).⁵ Second, global inequality has fallen over the past 10 years as Asia, and China in particular, has developed rapidly. Third, within many specific countries, the distribution of wealth has become more unequal. Fourth, enormous disparities of wealth between countries persist. For instance, Norwegians were around 10 times richer, on average, than Romanians in 2005, who were similarly 10 times richer than the average person in the poorest countries of sub-Saharan Africa (Hamilton and Hepburn, 2014). Finally, wealth is much more unequally distributed than income, which suggests that policies for redistribution of wealth within countries might need to focus on capital incomes (and inheritance taxes) as well as taxes on employment income.⁶ Other policies that appear important for reducing inequality and sustaining prosperity include support for human capital development through health and education systems that lead to higher real wages and increased living standards, along with efforts to prevent special interests from blocking the diffusion of prosperity.⁷

IV. System Stability and Resilience⁸

Macroeconomic textbooks still devote relatively few pages to understanding the extraordinary growth trends of the past 200 years (unprecedented in tens of thousands of

⁴See Persson and Tabellini (1994), Berg *et al.* (2012) and Piketty (2014).

⁵See Piketty and Saez (2003) and Alvaredo *et al.* (2013).

⁶Davies *et al.* (2011) find that the global wealth distribution is highly skewed, with a Gini coefficient of 0.802, while the comparable Gini for income is only 0.641 (Milanovic, 2006).

⁷See Acemoglu (2002), Goldin and Katz (2009), Lemieux (2006) and Helpman *et al.* (2010).

⁸This section builds upon work in progress by Farmer and Hepburn on the analogies between climate system modeling and financial system modeling for an interdisciplinary workshop at the Bank of England.

years of human civilization) and many more pages to explaining and managing the fluctuations around the trendline. While this is odd, fluctuations do, indeed, matter, as the enormous loss in social welfare following the financial crisis demonstrates. Just as prosperity cannot be understood solely by averages over people (see Section III) nor can it be understood simply from averages over time. Sustained prosperity implies economic and financial systems that have reasonable resilience to shocks.

There is much work to be done. The 2008 financial crisis revealed serious limitations in our understanding of the financial system, along with limitations in the economic models used by central banks, finance ministries and multilateral institutions. Former ECB President Jean-Claude Trichet noted, “As a policy-maker during the crisis, I found the available models of limited help. In fact, I would go further: in the face of the crisis, we felt abandoned by conventional tools.”⁹

One of the core challenges to face up to is that financial and economic systems are complex systems (Arthur, 1999; Beinhocker, 2006). Many environmental and ecological systems, including the climate system, are also complex systems (Rind, 1999). While the financial system is man-made, and, as such, the scope for large-scale intervention is perhaps greater than in physical systems at the planetary level, it has the additional subtlety of being a “complex reflexive system” (Beinhocker, 2013; Soros, 2013). Understanding the actions of individual agents requires understanding how such agents are themselves attempting to understand the behavior of other agents and the system as a whole.¹⁰ Models that do not start from this premise tend to fail to account fully for heterogeneity, out-of-equilibrium dynamics and contagion effects in financial networks.

The aggregate properties of complex systems, such as an economy, emerge from trillions of interactions between individual entities (e.g. particles or human agents). The following features are often present:

⁹“Reflections on the nature of monetary policy non-standard measures and finance theory,” a speech by Jean-Claude Trichet, President of the ECB, opening address at the ECB Central Banking Conference Frankfurt, 18 November 2010, accessed 27 March 2014 and available from: <http://www.ecb.europa.eu/press/key/date/2010/html/sp101118.en.html>.

¹⁰Bronk (2013), for instance, argues that the reflexivity of markets coupled with social networks and contagion of ideas and emotions may lead to “shared narratives and analytical homogeneity in markets,” where market participants go along with the crowd to save themselves the hassle of thinking for themselves. With insufficient cognitive diversity and/or heterogeneity of beliefs, Bronk (2013) argues that actors will not identify and address anomalies and novelties, increasing the potential for market instability.

- Significant feedbacks
- Thresholds, tipping points and nonlinearities, sometimes with irreversibilities
- Fat-tailed distributions, where there is a higher probability of events far from the mean
- Non-equilibrium system dynamics, often chaotic, that do not necessarily settle down
- Emergent properties that are highly sensitive to initial conditions.

Like the climate system, human financial systems have been experiencing the gradual build-up of pressures of various kinds (e.g. emissions in the atmosphere, greater financial market interconnectedness and household debt), shifting the systems into more uncharted territory (Caccioli *et al.*, 2011). In both cases, it is not unreasonable to suspect that these gradual shifts are creating greater fragility, rather than greater resilience.

The idea that there are similarities between the two systems is hardly novel (Farmer, 2002; Crutchfield, 2009; Hepburn, 2009). However, dwelling on the similarities briefly yields some possible advice for central bankers that could contribute to delivering more stable prosperity. One of the broad conclusions is that we are likely to be excessively confident about our predictions (Farmer and Hepburn, 2014). In a widely-cited paper, Svenson (1981) finds that over 90 percent of American and 69 percent of Swedish drivers rate themselves as better than the median driver in their country. A propensity for overconfidence is widely present in human judgments (Lichtenstein and Fischhoff, 1977; Harvey, 1997; Pallier *et al.*, 2002), even in some of the most careful scientific studies. This is particularly relevant to complex systems which are often by nature unpredictable. Nevertheless, we briefly outline five suggestions.

First, large datasets over long time series are very helpful in understanding complex systems, as such systems may explore spaces in the region of several attractors over time. In the climate system, paleoclimatology data from ice cores, tree rings, corals, oceans and lake sediments have been vital in understanding the sorts of states that are semi-stable and the types of transitions that are possible.¹¹ Data at many scales are required: it is impossible to properly understand a complex system with only aggregate data. Aggregate data and many time series at specific spatial locations are available for the climate system. While superior to the availability of financial system data, even this is not enough: climate scientists use “data models” to obtain a smooth and complete dataset for the globe that can be used

¹¹See useful data available at: <http://www.ncdc.noaa.gov/data-access/paleoclimatology-data>.

for subsequent modeling.

Second, less precision in reporting model results is likely to mean more truth.¹² Overconfidence is pervasive, and one should not expect estimates pertaining to the climate and financial systems to be immune, not least given that the relevant outputs are not fundamental physical constants, and, hence, could be wildly wrong. It is extremely difficult to predict some of the emergent properties of such systems, and yet economists and scientists make such predictions with error bars that continue to look remarkably narrow.

Third, a wide range of potential scenarios should be explored by government. Within the climate science community, a set of plausible scenarios is developed for use in climate modeling and research, and these are updated periodically, most recently in 2008.¹³ We must do our best to think through the failure nodes, whether it is the forests of the Amazon or the Lehman brothers.

Fourth, resilience should be considered to be an important concept, alongside efficiency.¹⁴ There may well be efficiency loss in a more resilient system, because resilient systems may have greater apparent redundancy. There is great social value in digging up and burning many fossil fuels: outlaw this too quickly, and not only will industry complain, but it will be more costly for society at large. Similarly, there is social value in allowing banks to have leveraged balance sheets. Increase buffers too much, and not only will the banks complain, but it will be more costly for society at large. However, to date, efficiency has comprehensively trumped resilience in both systems, and this needs to change.

Fifth, a precautionary approach that achieves an appropriate balance between resilience and efficiency is required in a complex system with unknown thresholds, nonlinearities and tipping points. Analysis can identify areas where there is reason to believe there may be a system boundary, or cliff edge, and create policy to ensure that the system does not drive off one of those cliff edges. An inevitable challenge is that we will not know precisely (or even vaguely) where the cliff edge stands, and the location of the cliff edge may move over time. The

¹²Accuracy is defined as the proximity of a measurement to its true value. Precision is defined as the degree to which repeated measurements show the same results, and is commonly expressed in statistics as the reciprocal of the variance.

¹³For instance, the most recent scenarios include four “representative concentration pathways” (RCPs), which describe plausible but very different greenhouse concentration trajectories, and, hence, four different climate futures. The four RCPs are named according to the radiative forcing in the year 2100, and, hence are called RCP2.6, RCP4.5, RCP6 and RCP8.5 (IPCC, 2008).

¹⁴There is more than one definition of resilience, but it is broadly the capacity of an ecosystem or other system to respond to a shock with relatively minimal damage and with a rapid recovery. When Greenland was 3 to 5°C warmer than today, a large proportion of the ice sheet had melted (Velicogna, 2009).

point is to allow an adequate buffer zone such that the risk of driving over the cliff is minimal. In regards to climate change, it now appears likely that the cumulative emission of 1 trillion tons of carbon might serve as one such system boundary (Rockström *et al.*, 2009; IPCC, 2014).

One might complain that it is almost impossible to set appropriate precautionary buffers if we do not know where the thresholds lie. However, in the climate system we now know enough to be certain that there are a lot of dangerous events that might occur. The feedbacks noted above, for instance, such as the thawing of the permafrost releasing methane or the collapse of the ice sheets, appear “too big to fail”: the latter could lead to meters of sea level rise, and, once gone, would not return before a substantial cooling of Earth towards ice age temperatures.¹⁵ The underlying problem in both systems is nonlinear positive feedback loops, which can enormously amplify modest effects. New methods are needed to model the integrated economy–energy–biosphere–environment system taking into account such nonlinearities, feedback loops, and heterogeneous agent behavior and evolution (Beinhocker *et al.*, 2013).

Finally, given that such systems are constantly evolving, policy must also continually evolve and adapt. Knowing this, the policy interventions can be designed to ensure the flexibility and optionality of responding in different ways in future are preserved. Although we recognize that sometimes it can be extremely important to signal forward commitment to markets in order to shape expectations in a socially useful manner, it is also useful to avoid needlessly locking policy into a regime that may subsequently turn out to be ill-suited to the system as it evolves and responds, including to policy announcements.

V. Conclusion

Scholarship on areas of green growth and sustainable prosperity should start from a clear understanding of the objective, and the implications of how that objective is measured. What is to be sustained? Mere output is far too narrow an objective, and market-based output even more narrow. If wealth is the objective (and this paper argues that it should be a serious candidate),¹⁶ then the frontier of research is now at the point of translating the well-developed theoretical economic literature into more detailed measures that appropriately capture the key concepts, improve the capture of relevant data, and create institutional

¹⁵When Greenland was 3 to 5°C warmer than today, a large proportion of the ice sheet had melted (Velicogna, 2009).

¹⁶See World Bank (2006), Hamilton (2014) and Barbier (2014).

momentum to complement GDP with new wealth (and potentially also prosperity) measures.¹⁷ With greater capacity for collection and analysis of extremely large datasets, statistical and econometric methods are now likely to be able to provide greater conceptual accuracy.

However, one single aggregate indicator will never be able to serve the required need: a dashboard of relevant indicators, including thresholds related to the food–energy–environment nexus¹⁸ and natural capital,¹⁹ needs to be developed into a form that could be more widely adopted.²⁰ With the objectives properly defined, the question of whether conventional economic growth can continue becomes subsidiary to the question of how the structure and nature of such growth can support continued and increasing prosperity in China and around the world.

In terms of understanding the underlying physical and social systems, the present paper has argued that complexity science and economics have a much greater role to play. For instance, agent-based modeling could be deployed to better understand conditions under which common-property resources could be managed effectively (Axtell and Epstein, 1996).

From an immediate and practical perspective, there are several policies that are worth exploring. The first is to reduce the subsidies spent annually on materials and resource use. Such subsidies provide incentives for firms to increase the use of natural resources, which may be associated with lower total factor productivity (Baptist and Hepburn, 2013). By one estimate, US\$1 trillion may be spent every year on directly subsidizing the consumption of resources (Dobbs *et al.*, 2011).

Second, pricing natural assets is critical. While the direct subsidies for resource use are vast, they are tiny compared with indirect subsidies created by the failure to properly price natural capital. The indirect subsidy associated with lack of payments for biodiversity loss and other environmental costs has been estimated at perhaps as much as US\$6.6 trillion (UNEPFI, 2011).

Third, countries should consider shifting their tax base away from labor, which correlates with higher total factor productivity (Baptist and Hepburn, 2013), and towards rents, materials and resources. Taxing environmental externalities and mineral rents are obviously economically rational.

These are mere first steps. Transitioning from the current unsustainable economic

¹⁷See Hamilton and Clemens (1999) and Weitzman (1976).

¹⁸See Mace (2014), Willis *et al.* (2014) and Allen and Frame (2007).

¹⁹Helm and Hepburn (2014).

²⁰Mace (2013).

model to a sustainably prosperous model appears, at this point, to be a mammoth undertaking. Empirically-grounded research that integrates the social and physical sciences will be needed to measure up to the challenge and to deliver the necessary changes in institutions, policies and business strategies to effect the transition.

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