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Shaky Foundations and Sustainable Exploiters: Problems With National Weak Sustainability Measures in a Global Economy

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Abstract

Macroeconomic sustainability indicators are often applied at the national level. This national-level focus is problematic given the importance of trade in the global economy. This article uses one measure of economic weak sustainability, Genuine Savings, to highlight three issues: (a) the national-level measure is empirically unsound because it does not provide a reliable indicator of weak sustainability for any trade-dependent nation; (b) it is normatively suspect because a nation can be labeled weakly sustainable even when its sustainability derives from the unsustainability of its trade partners; and (c) purported "sustainable" signals can encourage exploitative national policies. This article illustrates these conceptual problems, provides empirical case studies to establish their real-world relevance and importance, and discusses the implications for the indicator's application.

Keywords

national sustainability indicator, genuine savings, weak sustainability, international trade, natural resource depletion, globalization

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Introduction

Does the national focus of Genuine Savings (GS) compromise its usefulness and normative justification as a "weak sustainability" indicator when the nations in question are highly interconnected through trade? GS (also called *Adjusted Net Savings*) is a measure of weak sustainability (see Genuine Savings—Theory section; Asheim, 1997; Hamilton & Clemens, 1999). Recent recommendations to the French government proposing GS as an alternative to Gross Domestic Product (GDP) relegated trade issues to an appendix, signifying the need to further articulate the practical and normative implications of not considering trade (Stiglitz, Sen, & Fitoussi, 2009).

GS, as currently applied, does not accurately indicate weak sustainability when nations are linked through trade. GS measures change in the value of a domestic asset base, but how relevant is it to weak sustainability for policy makers to know if their national asset base is declining? The "Shaky Foundations Problem" (Shaky Foundations Problem section) demonstrates that an import-dependent nation can seem safely sustainable per GS yet face a completely predictable—and perilous—decline in welfare if its trading partners are not managing their own asset bases wisely.

The implications of a national sustainability measure also raise two normative concerns, illustrated by the "Sustainable Exploiter Problem" (Sustainable Exploiters Problem section). GS can label a nation sustainable when its sustainability derives from the *un*sustainability of other nations. This violates an intuitive motivation behind a *sustainable* label because it ignores both the moral consideration of others' interests and issues of responsibility. Furthermore, if policy makers only focus on ensuring their domestic sustainability, then use of GS might encourage exploitative behavior.

The article identifies conceptual problems with a national-level, aggregate weak sustainability measure and uses two empirical examples to show that these problems actually exist. The article raises fundamental concerns about using a national-level indicator in a globalized era and exposes challenges to achieving sustainability that policy makers using the indicator might encounter.

This article describes GS, then presents two conceptual problems along with real-world empirical evidence: the European Union's (EU) dependence on Brazilian beef illustrates the Shaky Foundations, and China's imports of raw natural resources from sub-Saharan Africa are a prime example of the Sustainable Exploiter. The article concludes with a discussion of potential solutions.

Genuine Savings

Motivation

A major driver of indices like GS is the need to replace GDP as an indicator of economic growth and well-being. Notwithstanding its widespread use, GDP has no theoretical link to human welfare (Stiglitz, 2009) and conveys little about the welfare prospects of future generations. GS "adjusts" GDP and is one of several candidate

replacement measures that consider a wider array of determinants of well-being (Fleurbaey, 2009; Stiglitz et al., 2009).

GS is central to research assessing the sustainability of an economy. Following the economics literature in defining sustainability as the indefinite maintenance of human welfare (Pezzey, 1992), a consistently negative GS signals an unsustainable development path because it indicates a drawdown of welfare-generating assets heralding a future decline in welfare (Hamilton & Clemens, 1999). For many nations, a persistently negative GS indicates that what seems like economic growth measured by GDP is actually a loss of wealth (World Bank, 2010).

Theory

Under certain assumptions, a change in welfare is related to a change in the total value of assets available for human consumption, called *comprehensive wealth* (Arrow et al., 2004; Hamilton & Atkinson, 2006). GS measures the change in comprehensive wealth (CW) over a period of time:

$$GS = \Delta CW = p_R \Delta K_R + p_N \Delta K_N + p_H \Delta K_H \quad (1)$$

where K_R is reproducible capital, K_N is natural capital, and K_H is human capital, whereas p_R, p_N, and p_H are each capital's shadow prices. Shadow prices reflect an asset's contribution to welfare. They are based on a forecast of the economy, taking into account future ecological, political, and economic interchanges (Dasgupta & Mäler, 2000).

Literature on sustainable development connects a change in comprehensive wealth, measured by GS, to weak sustainability (Arrow, Dasgupta, Goulder, Mumford, & Oleson, 2007; Arrow et al., 2004; Hamilton & Atkinson, 2006; Hamilton & Clemens,1999; Pearce & Atkinson, 1993). A perennial decline in welfare is by definition unsustainable, thus a persistent reduction of welfare-generating comprehensive wealth is also unsustainable. In the case of natural resource depletion, there are effectively three ways for a nation to maintain its stock of comprehensive wealth, and therefore to remain sustainable per GS. First, it could consume assets no faster than they are naturally replenished. Second, it could abide by the "Hartwick rule," reinvesting at least an equivalent value of the rent earned from consumed assets into other forms of welfare-generating capital (Hartwick, 1977). Third, it could advance technological change (Weitzman, 1997). The substitution assumption and the promise of technological change are both sensitive to imputed shadow prices and underlie a schism between "weak" sustainability, which allows a certain degree of substitution, and "strong" sustainability, which requires limits to substitution of critical capital forms (Martinez-Alier, 1995; Neumayer, 2003).

Empirics

GS's current application is limited to modeling closed economies and measuring change in national comprehensive wealth (Atkinson & Hamilton, 2002; Proops,

Atkinson, Schlotheim, & Simon, 1999; Vincent, Panayotou, & Hartwick, 1997). Most environmental goods and services are omitted due to its bias toward market-based assets, although some pollution externalities are considered (World Bank, 2011). Improved methods and data are leading to progressively better estimates of environmental assets as well as adjustments for technological change, population growth, and capital gains.

Estimating depreciation of exhaustible resources has undergone significant revision in recent years (Atkinson & Hamilton, 2007; Hamilton & Ruta, 2009; Neumayer, 2000; World Bank, 2006, 2011). Estimated rents are crucial to determining whether a nation is meeting the Hartwick rule, and different methods produce wildly differing results (Atkinson & Hamilton, 2007). Even with these improvements, however, current reliance on market prices ignores the costs of production externalities and could encourage loss of critical natural capital and underreinvestment (Muradian & Martinez-Alier, 2001).

Technological change increases the efficiency of an economy and in the long-term may play a significant role in a nation's sustainability (Weitzman, 1997). Arrow et al. (2007) find that the magnitude of technological change can overshadow the change in measured wealth in some nations. Similarly, population growth rates can invert the sign of growth from apparent wealth accumulation to depletion when considered on a per-capita basis (Arrow et al., 2007; Ferreira, Hamilton, & Vincent, 2008).

Last, including capital gains in GS estimates could be important for sustainability, especially in resource-rich nations (Dasgupta & Mäler, 2000; Hamilton & Bolt, 2004). Capital gains for resource exporting countries arise from improved terms of trade as resource prices increase due to scarcity. Ignoring capital gains underestimates the sustainability of resource-rich, net-exporting nations, and overestimates that for resource poor, net-importing nations (Arrow et al., 2007; Hartwick, 1995; Sefton & Weale, 1996).

Shaky Foundations Problem

National-level GS can fundamentally fail to ensure sustainability because of its exclusive focus on nationally owned resources. If a nation's welfare is strongly tied to international partners, its sustainability could be threatened by economic distress in trading partners. Empirical estimates of GS offer little insight into potential unsustainability due to international interactions, suggesting it is an incomplete measure of national weak sustainability.

As global trade has increased, so has economic dependence on imports in many countries. Countries are increasingly interconnected through trade (Figure 1): Imports represent at least half of the GDP of 47 countries, and exports make up the majority of GDP for 68 countries (World Bank, 2010).

Three cases of economic disruption abroad might endanger a trade-dependent nation's weak sustainability: (a) a sudden international macroeconomic shock in trading partners, (b) long-term macroeconomic problems in trading partners, and (c) depletion of particular resources in an apparently macroeconomically healthy trading partner.

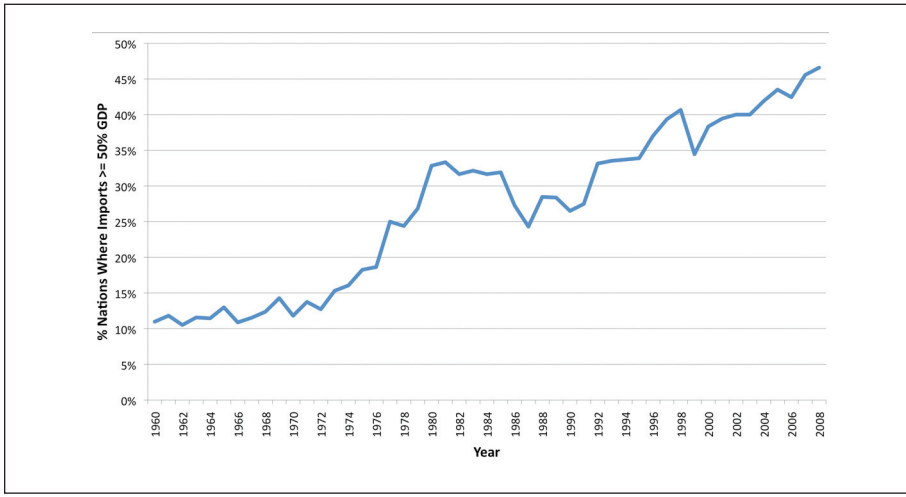

Figure 1. Percentage of nations where imports represent at least 50% of GDP (World Bank, 2010)

First, an international macroeconomic shock in trading partners could imperil the weak sustainability of linked nations. The Argentine financial crisis in early 2000s and the Asian crisis in late 1990s illustrate that a sudden economic collapse in one nation has cascading influences in its trading partners. A weak sustainability indicator might foreshadow future economic crashes, but it seems too ambitious to demand more of a sustainability indicator than what the best available macroeconomic measures can deliver (Grabel, 2003).

Considering the second case, economic ties may also be disrupted due to long-term macroeconomic problems in important trading partners, for example, due to poor institutions and policies leading to a dearth of investment or an excess of consumption. As Atkinson and Hamilton (2002) argue, it is in the self-interest of decision makers to consider the long-term sustainability of economic partners, and the economic partner's negative GS should generate caution in an economically tied nation worried about its own sustainability. Theoretically, an importer's GS would also indirectly reflect these macroeconomic problems in trading partners via an economic forecast and shadow prices that incorporate the risk of future instability and potential supply disruption. Empirically, current methods of estimating natural resource prices, in particular, poorly incorporate future risks. As currently calculated, national GS does not reflect the unsustainability of partners and thus decision makers who are myopically focused on their own assets (and GS) may make poor policy choices that could negatively affect their own future sustainability.

The final case of economic disruption may occur when a trading partner in seemingly strong macroeconomic health nonetheless threatens the weak sustainability of an importer. This could arise from the unsustainable management of a component of the

trading partner's assets on which the importer is particularly dependent. In this case, the trading partner's GS would be positive but the weak sustainability of the importer is nonetheless not assured.

Take as an example a nation whose economy relies on imports of natural resources or natural resource-intensive products. The importer's ability to maintain a positive GS depends on the future prices of natural resources as well as the ability to find trade partners willing to accept the costs of depletion and environmental degradation. This pattern can be generalized: Wealthy countries rely on a steady stream of cheap resources, which they maintain via declining terms of trade, especially for natural resources (Hornborg, 2006, 2009; Muradian, O'Connor, & Martinez-Alier, 2002; Russi et al., 2008). The stream continues even when world market prices for the resources are declining because nations burdened with international debt tend to increase resource exports to earn foreign exchange (Atkinson & Hamilton, 2002; Muradian & Martinez-Alier, 2001).

For a number of reasons, this pattern may not endure, threatening the sustainability of importers. Exporting nations may adjust the price of exports as resources become scarce, environmental externalities become evident, or society's values shift (Arrow et al., 1996; Chichilnisky, Heal, & Beltratti, 1995; Ekins, 1993; Goodland & Daly, 1993; Martinez-Alier, 1993; Martinez-Alier, Munda, & O'Neill, 1999; O'Neill, 1997a). If assumptions about capital gains or technological change are incorrect, resources may become overexploited and exports may cease (Bretschger, 2005; del Mar Rubio, 2004; Georgescu-Roegen, 1984; van den Bergh & Verbruggen, 1999). These eventualities could be reflected in the shadow price imputed to the resources and thus be reflected in GS but currently are ignored by using market prices to determine natural capital depletion and capital gains.

These cases demonstrate that GS may provide accurate information on changes in domestic wealth, but for nations depleting their natural resources or relying on imported natural resources, GS does a poor job of measuring weak sustainability. Accurate shadow prices and consideration of international interactions are fundamental to conclusions about sustainability based on GS (Atkinson & Hamilton 2007; Proops et al., 1999). If decision makers in an importing nation were to rely exclusively on GS, as currently calculated, as an indicator of weak sustainability, they might violate the sustainability principle and not ensure their citizens' welfare. Of course, this is predicated on an assumption that states have an obligation to strive for economic sustainability.

Sustainable Exploiters Problem

The Sustainable Exploiter Problem also results from GS' national focus but asks a different question than the Shaky Foundations Problem: Even if a nation's weak sustainability was guaranteed by a positive GS, might the national-level focus of GS lead to moral concerns? Imagine a world with an endless number of nations willing to export their natural resources. Upon full depletion of one exporter, an importer moves

on to the next one. In this way, the importer will be weakly sustainable forever, leaving a long line of depleted nations in its wake. This case raises moral concerns for both nations. Three distinct issues arise: (a) Do export policies violate governmental commitment to citizens? (b) Do imports abet mismanagement? and (c) Does GS encourage exploitation?

Do Export Policies Violate Governmental Commitment to Citizens?

Under certain circumstances, an exporting nation may not meet a sustainability commitment by achieving a positive GS. Decision makers may suspect that a positive GS is based on an erroneous forecast or inaccurate shadow prices. Natural resource flows are generally imbalanced even when standard economic accounts between trade partners are balanced (Proops et al., 1999), so the sustainability calculation could shift dramatically from higher deductions using more accurate shadow prices for natural resource exports. In setting export policy, decision makers should contemplate the difficulties in imputing accurate shadow prices to ensure that full compensation is received and in these cases be cautious about using an unadjusted GS.

In a more straightforward case, decision makers in an exporting nation may violate a weak sustainability commitment to their citizens if they knowingly allow GS to be negative. In the case of corrupt governments, their pursuit of foreign exchange derived from the sale of assets for nefarious purposes is a clear violation of moral responsibility. Indeed, corruption in natural resource-rich countries is linked with decreased GS (Dietz, Neumayer, & De Soysa, 2007), evidence that the corrupt governments are either underpricing resources or underreinvesting rents.

The sustainability commitment may be violated even in cases where the government is pursuing export policies it thinks will benefit the future, but which drive GS negative. A government may enact unsustainable policies, say, to jumpstart economic growth or in the expectation that technological change will reverse depletion trends. In pursuing an unsustainable development path, however temporary, decision makers must assess the risk that the path may not lead to sustainability. There is ample empirical evidence that technological change and capital gains may be insufficient to offset natural capital losses (Arrow et al., 2007; Bretschger, 2005; del Mar Rubio, 2004). Another example is the lack of gains from trade when that trade is based on export of natural resources.

In producing natural resource-intensive goods or raw materials, comparative advantage may be gained when a country has high assimilative capacity for pollution or abundant natural resources. Ricardo's law of comparative advantage forms the basis for modern theory regarding the economic gains from trade, postulating that countries should specialize in goods for which they have a technological advantage (Ruffin, 2002). Heckscher and Ohlin built on this theory to argue that countries should produce and export the commodities that they can produce most efficiently in exchange for products they cannot (or only expensively) produce. Economic openness can spur growth through investment and adoption of new technologies (Lopez, 1994), and there

are cases of positive empirical effects on sustainability as measured by GS (De Soysa & Neumayer, 2005; Vincent, 1997).

Critics have pointed out, however, that this apparent comparative advantage might be false, due only to a lack of property rights over resources (Chichilnisky, 1993, 1994), lack of internalization of externalities (Ekins, Folke, & Costanza, 1994; Martinez-Alier, 1993; Pethig, 1976), or short-term profit seeking by cash-strapped governments with high levels of external debt or corruption (Dietz, Neumayer, & De Soysa, 2007; Gullison & Losos, 1993; Leite & Weidmann, 2002). In cases of false comparative advantage or where assumptions about technological change and its ability to overcome scarcity of natural capital are incorrect (Georgescu-Roegen, 1984; Martinez-Alier, 1995), instead of increasing growth and welfare due to openness, specialization in natural resource–intensive export sectors can reduce economic production and welfare (Chichilnisky, 1994; Margolis, 2009), make countries more susceptible to shocks (Isham, Woolcock, Pritchett, & Busby, 2005; Sachs & Warner, 1999), and may be welfare reducing (Redding, 1999).

Do Imports Abet Mismanagement?

Agents in the exporting nation are not the only responsible parties. The importer may be behaving wrongly in relation to an exporter's citizens as well. If a nation takes seriously the need to provide nondeclining welfare for its citizens, it should not base that welfare on the reduction of welfare abroad. This violates an intuitive motivation underlying the sustainability principle.

Under some circumstances, the importer may be knowingly encouraging the exporter's unsustainable policies. Specifically, the importer may have good grounds to believe that the exporter's decision makers do not have the interests of their citizens in mind in pursuing such policies or that they are misinformed about the policies' welfare effects. Although this is a complicated matter, it seems plausible to think that at least under some circumstances importers should not knowingly abet the mismanagement of exporters' resources. An example of potential complicity in mismanagement draws on the Shaky Foundations discussion about rich countries' reliance on cheap inputs to fuel their consumption and declining terms of trade in their poorer trading partners. Importers may write off such an injustice to laissez-faire international free trade policies, giving any number of justifications for continuing to import natural resources, including claiming that adequate protection of environmental resources is an issue of national sovereignty or that exporters have the right to use natural resources as fuel for economic development. However, an importer's actions may be pivotal in a way that implicates it in the inappropriate actions of an exporter toward its own citizens: It fulfills its own obligation to provide nondeclining human welfare for its citizens by abetting the decline in the welfare of citizens in its trade partners.

Importers may even be obliged to take substantive action to avoid abetting mismanagement by putting conditions on imports, developing partners' capacity for sustainable resource management, or seeking international consensus on environmental rules. The notion of international action to halt unsustainable environmental behavior in

economic partners has precedents. Importing nations have placed restrictions on the behavior of their trade partners to improve management of fish stocks (Tyler, 2007), forests (Nepstad, Stickler, & Almeida, 2006), and endangered species (DeSombre & Barkin, 2002), and cases are emerging where trade sanctions aim to mitigate damage to the global commons (Barrett, 1994; Charnovitz, 2003; Waye, 2008). International trade regulatory bodies, such as the WTO, have accepted unilateral trade sanctions as legitimate avenues to environmental protection (Berger, 1999; Charnovitz, 1994; Howse, 2002).

Does GS Encourage Exploitation?

Even if an importer was not guilty of abetting mismanagement, national level GS faces a further fault. The Sustainable Exploiter Problem illustrates that striving for a positive GS could encourage nations to exploit others because only the consumption of domestic resources reduces their nation's GS. This also runs counter to the spirit motivating a sustainability indicator.

Decision makers who are exclusively accountable for ensuring their own nation's positive GS may seek resources from other nations who value their resources less. In theory, this is the point of international trade. Nations with abundant resources capitalize on their comparative advantage by exporting them to nations which are willing to pay a premium. Unequal exchange arises, however, when the gains from trade are lost. Abundant cases document that improved environmental conditions in richer countries have come at the cost of depletion of resources and increased deterioration in developing countries (Chichilnisky, 1994; Giljum & Eisenmenger, 2004; Goodland & Daly, 1993; Hornborg, 2009; Martinez-Alier, 1993; Muradian & Martinez-Alier, 2001; Muradian et al., 2002; Srinivasan et al., 2008; Weisz, 2007). To make matters worse, these costs are often borne by lower income groups within exporting nations (Srinivasan et al., 2008), and the net outflow of material resources can exacerbate social conflicts and local environmental impacts (Vallejo, 2010) evoking environmental justice issues.

Moreover, as discussed, achieving national weak sustainability depends on continued, cheap imports of natural resources, usually from developing countries where environmental assets are valued less. There are many reasons a nation might sell resources at below their theoretical economic value, including difficulties in estimating the social value of the resources, government corruption, international power imbalances leading to disadvantageous trade agreements, desperate exchanges provoked by poverty, illegal extraction by agents seeking private gain, and weak institutions that fail to protect the social interest. International asymmetries in the value placed on natural resources intensify natural resource exploitation in less developed exporters, encourage environmental load displacement and cost shifting from wealthier nations, and can increase international inequities due, in part, to inadequate compensation (Behrens, Giljum, Kovanda, & Niza, 2007; Giljum & Eisenmenger, 2004; Hornborg, 2009; Jayadevappa & Chhatre, 2000; Lindert & Williamson, 2003; Muradian & Martinez-Alier, 2001; Muradian et al., 2002).

Other claims of positive linkage between trade and weak sustainability might actually support the claim that some nations are achieving their sustainability by causing

other nations to be unsustainable. De Soysa and Neumayer (2005) show that countries more open to trade have higher GS rates, thus concluding that globalization is good for sustainability. An alternative interpretation is that nations can increase their weak sustainability by increasing their imports, particularly from resource-extracting countries. Indeed, although the link between trade openness and GS is clear for most nations in their study, the authors do not find positive linkages in natural-resource dependent, lower income countries, the nations that are most vulnerable to exploitation.

In promoting GS as a sustainability indicator, a relevant question is *how* positive savings is achieved, not just *if* it is. A nation can avoid drawing down its natural capital by implementing policies to protect its forests, water, and air, but under the national-level GS sustainability criterion, it does not need to limit its consumption habits that degrade and deplete the environment. It just needs to locate other nations willing to accept those losses. This would be less objectionable if environmental quality was not systematically undervalued in poorer nations, if the exploited nations received full compensation for the depletion and degradation, and if there was not a pattern of poor governance in many resource-rich, income-poor countries. In reality, we have a situation where the "sustainability measure" instead may reinforce potentially unsustainable and morally corrupt exploitative behavior. That national-level GS raises such fundamental normative problems strongly suggests national-level GS, in its current incarnation, is at best an inadequate indicator of a nation's weak sustainability.

Shaky Foundations Case: The EU's Dependence on Brazilian Agriculture

The EU's dependence on Brazilian agriculture is a case where GS does not warn of unsustainability derived from undervaluation and consequent mismanagement of natural resources in trading partners.

Europeans consume large quantities of agricultural imports from Brazil. Europe's heavy reliance on agricultural imports from Brazil is reinforced by preferential import policy for Brazilian beef and soy due to concerns about health and genetically modified crops. Brazil now supplies more than three quarters of the EU's beef and one half of its soymeal and soybeans (Kaimowitz, Mertens, Wunder, & Pacheco, 2004; Nepstad et al., 2006).

Brazil's current production model of clearing forest to expand export production is depleting its natural capital. Brazil's beef and, to a lesser extent, soy industries, coupled with their requisite roads and workers, encourage rapid conversion of forest to pasture and cropland (Fearnside, 2002; Morton et al., 2006; Nepstad et al., 2006). If deforestation trends continue, more than half of the original forest cover of 384 million hectares will be lost by 2050 (Instituto Nacional de Pesquisas Espaciais, 2009; Malhi et al., 2008; Soares-Filho et al., 2006).

Economic losses from deforestation are significant and are unlikely to be fully recovered through agricultural profits (Arima, Barreto, & Brito, 2006; del Carmen Vera Diaz & Schwartzman, 2005; Margulis, 2003). Using a midrange estimate of the

value of local nontimber forest ecosystem services provided by the Amazon, deforestation between 1995 and 2008 resulted in an annual loss of local nontimber forest services of around US$3.5 billion (Andersen, 1997; Margulis, 2003; Peters, Gentry, & Mendelsohn, 1989; Torras, 2000).[1] Upward of US$9 billion in potential carbon sequestration payments were also lost.[2]

Even considering the cost of deforestation, Brazil historically has not been a weakly unsustainable nation. Incorporating the lost value of local and global ecosystem services, Brazil's GS was 2.9% in 2005 (or 4.0% just considering local losses; Arrow et al., 2007). Further pressures to deforest (Naylor et al., 2005; Soares-Filho et al., 2006), declines in agricultural production due to positive deforestation-precipitation decline feedback loops (Malhi et al., 2008), and increasing value placed on globally important standing forests might reduce GS, but it is unlikely that its GS will dip negative.

The case is illustrative of the EU's susceptibility to its trading partners' unsustainable production practices. Although aggregate GS is insensitive to declines in any particular component of capital, the EU could look at the loss of forest value to uncover shaky foundations of its imports. The EU might predict price increases as Brazil internalizes social losses into the price of agricultural export products, but finding other trading partners that meet the EU's public health standards will become increasingly difficult as the Earth's forest cover continues to decline and arable land is fully used. The EU should worry that a major pillar of their agricultural consumption, and therefore welfare, depends on an unsustainable supply model.

Sustainable Exploiter Case: China's Imports of African Resources

Many nations maintain high consumption levels by importing natural resources and natural resource–intensive products from abroad. One case is China, whose GS is positive, and the GS-negative nations in sub-Saharan Africa (SSA) that supply much of China's raw material for growth. By diversifying its sources of raw materials across many African and Asian nations, China is buffering itself from depletion within any given trading partner. China is also serially contributing to natural capital declines in nations notoriously bad at safeguarding public interest.

Imports of natural resources from SSA are crucial to China's economic boom. By standard economic output measures, China's economic performance over the past 30 years made it the second biggest economy in the world (Bloomberg News, 2010). Rapid growth in China's per capita comprehensive wealth has been driven by increasing reproducible capital, which derives, in turn, from infrastructure and manufacturing sectors (Arrow et al., 2007; Bloomberg News, 2010). These sectors of the Chinese economy are natural resource intensive, fueling China's appetite for raw materials such as oil, iron ore, and copper (Reisen, 2007), and increasingly these inputs are coming from abroad, particularly from SSA (Bloomberg News, 2010; Goldstein, Pinaud, Reisen, & Chen, 2006; Kaplinsky, McCormick, & Morris, 2007; Morrison, 2008; Renard, 2011; Tull, 2006; Zafar, 2007). Trade flows between China and SSA reflect

Table 1. Genuine Savings of China's Key Trading Partners in 2007 (Expressed as Percentage of Gross National Income; World Bank, 2010)

	GS	Energy depletion	Mineral depletion
Angola	–36	56	0
Cameroon	6	6	0
DRC	0	3	3
Congo	–23	57	0
Equatorial Guinea	–39	93	0
Gabon	2	33	0
Ghana	12	0	5
Kenya	13	0	0
Nigeria[a]	—	25	0
South Africa	1	3	2

a. No GS reported for Nigeria due to lack of data on net savings.

economic theory, including the law of comparative advantage and the Heckscher-Ohlin model, where SSA exports raw materials and imports cheap, labor-intensive goods (van Dijk, 2009; Zafar, 2007).

The relationship with China is vital to these SSA nations' economies. China has become SSA's second most important trade partner after the European Union. China's direct investment has surpassed US$1 billion annually, and its aid rivals Western donors' (Renard, 2011; van Dijk, 2009; Zafar, 2007). China's engagement has had positive economic effects for some African trade partners, including increased GDP growth rates, improved terms of trade, access to cheap consumer products, and expanded export volumes and aid, but not for all nations, in part because the lack of good governance in many raises the specter of the "resource curse" and "Dutch disease" (Brautingham, 2009; Collier & Gunning, 1999; Reisen, 2007; Renard, 2011; van Dijk, 2009; Zafar, 2007).

To varying degrees, natural resource depletion is drawing down GS in all these nations (see Table 1), in large part driven by China's raw material demand. Oil depletion is responsible for the strikingly negative GS rates in the least sustainable nations. Four of the six nations exporting crude to China are among the six least sustainable nations on earth. According to an OECD study, 81% of Sudan's crude oil exports go to China, 31% of Congo's, and 25% of Angola's (Kaplinsky et al., 2007). Exports of metals and timber tell a similar story about China's appetite. Unfortunately, GS still does a poor job of capturing the value of forest depletion, so although at least 5 nations export timber to China, none have deductions for their forest depletion. The evidence indicates that many of the governments of SSA nations are not reinvesting enough of the profits from natural resource extraction to ensure their country's sustainability despite strong GDP growth in some nations (failing the Hartwick rule). What is worse,

the estimated deductions are likely far below the true social losses of these resources so the situation is less sustainable than these figures state.

Especially in fragile nations, export of natural resources gives cause to worry, as it is unlikely that these leaders have the best interest of their citizens in mind when agreeing to trade deals, and may not seek to ensure the long-term welfare of their citizens. Dependence on natural resource commodity exports is associated with corruption (Leite & Weidmann, 2002), and specialization in these sectors can impair economic efficiency and diversification (Renard, 2011). China has a reputation of turning a blind eye toward dubious regimes and environmental and labor concerns in its trade partners (van Dijk, 2009; Zafar, 2007). Angola, Sudan, the Democratic Republic of Congo, and Equatorial Guinea supply China with oil, metals, and timber (Goldstein et al., 2006). Even in cases where SSA governments are acting in good faith, evidence is mounting of devastating economic effects from windfall profits from natural resource extraction (van Dijk, 2009; Zafar, 2007). Moreover, the heavy dependence of some SSA nations on China makes them vulnerable to price-fixing and other pressures to reduce the compensation they demand for their natural capital depletion (Renard, 2011).

Although China maintains a high, positive per capita GS, suggesting that its economic growth is weakly sustainable, much of that growth depends directly on material imports from nations whose economies are unsustainable. Also, these countries' very unsustainability stems from China's demand for their natural resource stocks. It can be fairly said that China fulfills the role of a Sustainable Exploiter. The implication of this real-world case is that, under the national GS framework, one nation's weak "sustainability" might depend on declines in other nations' welfare.

Conclusions

Three reasons lead to a conclusion that national level GS fails as a weak sustainability indicator when the nations in question are highly interconnected through trade,

1. When applied at a national level, GS is empirically deficient because it does not reflect impending import declines from important trade partners. Some of the highlighted concerns from the Shaky Foundations Problem could be addressed by better economic forecasts and more accurate shadow prices for resources. A second best solution would be for an importing nation to examine the breakdown of its trading partner's GS to ensure that the natural resources in question are well managed. That, coupled with the stable economic welfare that a positive GS indicates, may be the best assurance an importer can have regarding the sustainability of their natural resource provenance.

The last two reasons are illustrated by the Sustainable Exploiter Problem:

2. GS ignores issues of the moral consideration of others' interests and responsibility.
3. GS can encourage exploitative behavior.

In a one-nation model, responsibility falls on domestic agents to ensure that natural resources are exchanged at their social value and that profits are reinvested in the economy. When nations are using each other's resources, the lines of responsibility become less clear. Importers have a number of ways to handle the concerns raised. They can support good governance in their trade partners, set up certification schemes, and, as a last resort, make trade conditional on sustainable practices. They can support efforts to accurately assess the true value of a healthy environment and integrate non-market values into policy. Moreover, perhaps most importantly, they should be willing to compensate partners for the full social value of their imports.

Within the GS framework, an apparent solution to the Sustainable Exploiter Problem is GS applied at the global scale. Although this might better quantify global environmental depletion, neither would a summary global measure do anything to expose the exploitative behavior of forcing some nations to accept the social costs of others' consumption nor would it provide clear policy guidance.

One promising solution to the Sustainable Exploiter Problem that is worth researching further would be to account for imports of underpriced resources in an importing nation's GS as a type of "sustainability liability" (Proops et al., 1999). This would require determining a nation's derived demand for natural resources, then deducting the value of that depletion from the consuming nation's accounts. Alternatively, Atkinson and Hamilton (2002) propose an "ecological balance of payments" that assigns partial responsibility to the consuming nation for the exporter's negative GS, reflecting the role of domestic policy failures. These could be paired with a "natural resource depletion tax" (Muradian & Martinez-Alier, 2001) or "ecological footprint-based debt relief" (Torras, 2003) to compensate exporters for the costs of depletion. These solutions might help curtail an importer's negligence toward, and moral hazard in encouraging, poor governance by their trading partners and would reflect the portion of responsibility a consuming nation bears for its trading partner's unsustainability.

Given more accurate valuations, both approaches could reflect the discrepancy between the price an importing nation paid for natural resources and the social value that should have been paid. Our methods for accurately assessing the full ecological and social values of natural resources and the environment have greatly improved over the past decades (Garrod & Willis, 1999; Haab & McConnell, 2002; Hoyos, 2010), but in many ways these methods are still in their infancy. The research program underpinning GS needs to focus on developing and integrating holistic, accurate valuations. Empirical studies can then routinely perform the necessary analyses for inclusion in national accounts. International and national actors need to then build incentives and enact policies to encourage the use of these figures in decision making. Crucially, we must recognize where our valuation methods are philosophically or practically unable to reach accurate estimates and build other strategies for dealing with the shortcomings within a national sustainability measure. For example, many ethical issues regarding incommensurate values cannot be handled in the GS framework (Daily et al., 2000; Martinez-Alier et al., 1999; O'Neill, 1997b; Spash, 1993; Sunstein, 1993).

In sum, developing macroeconomic social welfare indicators that better reflect the broad base of welfare-generating capital is an important pursuit, considering the ubiquity of inaccurate and inadequate proxies currently in use, such as GDP. National GS provides information on domestic wealth, but, as currently constructed, it constitutes an incomplete and morally suspect weak sustainability indicator given its lack of reflection of international trade.

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Notes

1. Assuming 80% of forests provide ecosystem services worth US$122/hectare/year (midpoint of range US$15-US$290), the NPV = US$1,875/hectare ($\delta = 5\%$, $t = 30$ years).
2. One deforested hectare could earn US$5,000, based on US$50 per ton of carbon (Tol, 2009) and 100 tons per hectare (Houghton, Lawrence, Hackler, & Brown, 2001). The price per ton could vary greatly depending on the applied social discount rate (Dasgupta, 2007; Stern, 2006).

References

Andersen, L. (1997). *A cost–benefit analysis of deforestation in the Brazilian Amazon*. Rio de Janeiro, Brazil: Instituto de Pesquisa Econômica Aplicada (IPEA).

Arima, E., Barreto, P., & Brito, M. (2006). *Cattle ranching in the Amazon: Trends and implications for environmental conservation*. Belém, Brazil: Instituto do Homem e Meio Ambiente da Amazônia. Retrieved from http://www.imazon.org.br/novo2008/arquivosdb/141708ea_5e.pdf

Arrow, K. J., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. S., . . . Pimental, D. (1996). Economic growth, carrying capacity, and the environment. *Ecological Applications, 6*(1), 13-15.

Arrow, K. J., Dasgupta, P., Goulder, L., Daily, G., Ehrlich, P., Heal, G., . . . Walker, B. (2004). Are we consuming too much? *Journal of Economic Perspectives, 18*(3), 147-172.

Arrow, K. J., Dasgupta, P., Goulder, L., Mumford, K., & Oleson, K. L. L. (2007). *China, the U.S., and sustainability: Perspectives based on comprehensive wealth* (Stanford Center for International Development Working Paper 313). Retrieved from http://www.ucl.be/cps/ucl/doc/core/documents/Dasgupta.pdf

Asheim, G. B. (1997). Adjusting green NNP to measure sustainability. *Scandinavian Journal of Economics, 99*, 355-370.

Atkinson, G., & Hamilton, K. (2002). International trade and the "ecological balance of payments." *Resources Policy, 28*(1), 27-37.

Atkinson, G., & Hamilton, K. (2007). Progress along the path: Evolving issues in the measurement of genuine saving. *Environment and Resource Economics, 37*, 43-61.

Barrett, S. (1994). *Trade restrictions in international environmental agreements* (CSERGE Working Paper No. 94-13). London, UK: CSERGE.

Behrens, A., Giljum, S., Kovanda, J., & Niza, S. (2007). The material basis of the global economy: Worldwide patterns of natural resource extraction and their implications for sustainable resource use policies. *Ecological Economics, 64*, 444-453.

Berger, J. R. (1999). Unilateral trade measures to conserve the world's living resources: An environmental breakthrough for the GATT In the WTO turtle case. *Columbia Journal of Environmental Law, 24*, 355-412.

Bloomberg News. (2010, August 16). *China overtakes Japan as world's second-biggest economy*. Retrieved from http://www.bloomberg.com/news/2010-08-16/china-economy-passes-japan-s-in-second-quarter-capping-three-decade-rise.html

Brautingham, D. (2009). *The dragon's gift in Africa: The real story of China in Africa*. Oxford, UK: Oxford University Press.

Bretschger, L. (2005). Economics of technological change and the natural environment: How effective are innovations as a remedy for resource scarcity? *Ecological Economics, 54*, 148-163.

Charnovitz, S. (1994). Environmental trade sanctions and the GATT: An analysis of the Pelly Amendment on foreign environmental practice. *American University Journal of Environmental Law and Practice, 9*, 751-807.

Charnovitz, S. (2003). *Trade and climate: Potential conflicts and synergies*. In Pew Center (Ed.), *Beyond Kyoto* (pp. 141-164). Arlington, VA: Pew Center Global Climate Change. Retrieved from http://www.pewclimate.org/docUploads/Trade%20and%20Climate.pdf

Chichilnisky, G. (1993). North–South trade and the dynamics of renewable resources. *Structural Change and Economic Dynamics, 4*, 219-248.

Chichilnisky, G. (1994). North–South trade and the global environment. *American Economic Review, 84*, 851-874.

Chichilnisky, G., Heal, G., & Beltratti, A. (1995). The green golden rule. *Economic Letters, 49*, 175-179.

Collier, P., & Gunning, J. W. (1999). Why has Africa grown slowly? *Journal of Economic Perspectives, 13*(3), 3-22.

Daily, G. C., Söderqvist, T., Aniyar, S., Arrow, K. J., Dasgupta, P., Ehrlich, P. R., . . . Walker, B. (2000). The value of nature and the nature of value. *Science, 289*, 395-396.

Dasgupta, P. (2007). Commentary: The Stern review's economics of climate change. *National Institute Economics Review*, *199*, 4-7.

Dasgupta, P., & Mäler, K.-G. (2000). Net national product, wealth, and social well-being. *Environment and Development Economics, 5*, 69-93.

De Soysa, I., & Neumayer, E. (2005). False prophet, or genuine savior? Assessing the effects of economic openness on sustainable development, 1980-99. *International Organization, 59*, 731-772.

del Mar Rubio, M. (2004). The capital gains from trade are not enough: Evidence from the environmental accounts of Venezuela and Mexico. *Journal of Environmental Economics and Management, 48*, 1175-1191.

DeSombre, E. R., & Barkin, S. (2002). Turtles and trade: The WTO's acceptance of environmental trade restrictions. *Global Environmental Politics, 2*(1), 12-18.

del Carmen Vera Diaz, M., & Schwartzman, S. (2005). Carbon offsets and land use in the Brazilian Amazon. In P. Moutinho & S. Schwartzman (Eds.), *Tropical deforestation and climate change* (pp. 93-100). Belem, Brazil: Amazon Institute for Environmental Research.

Dietz, S., Neumayer, E., & De Soysa, I. (2007). Corruption, the resource curse and genuine saving. *Environment and Development Economics, 12*(1), 33-53.

Ekins, P. (1993). "Limits to growth" and "sustainable development": Grappling with ecological realities. *Ecological Economics, 8*, 269-288.

Ekins, P., Folke, C., & Costanza, R. (1994). Trade, environment and development: The issues in perspective. *Ecological Economics, 9*, 1-12.

Fearnside, P. M. (2002). Soybean cultivation as a threat to the environment in Brazil. *Environmental Conservation, 28*(1), 23-38.

Ferreira, S., Hamilton, K., & Vincent, J. R. (2008). Comprehensive wealth and future consumption: Accounting for population growth. *World Bank Economic Review, 22*, 233-248.

Fleurbaey, M. (2009). Beyond GDP: The quest for a measure of social welfare. *Journal of Economic Literature, 47*, 1029-1075.

Garrod, G., & Willis, K. (1999). *Economic valuation of the environment*. Cheltenham, UK: Edward Elgar.

Georgescu-Roegen, N. (1984). Feasible recipes versus viable technologies. *Atlantic Economic Journal*,12(1), 21-31.

Giljum, S., & Eisenmenger, N. (2004). North–South trade and the distribution of environmental goods and burdens: A biophysical perspective. *Journal of Environment and Development, 3*, 73-100.

Goldstein, A., Pinaud, N., Reisen, H., & Chen, X. (2006). *The rise of China and India: What's in it for Africa?* Paris, France: OECD.

Goodland, R., & Daly, H. (1993). Why Northern income growth is not the solution to Southern poverty. *Ecological Economics, 8*, 85-101.

Grabel, I. (2003). Predicting financial crises in developing economies: Astronomy or astrology? *Eastern Economic Journal, 29*, 243-258.

Gullison, R. E., & Losos, E. C. (1993). The role of foreign debt in deforestation in Latin America. *Conservation Biology, 7*(1), 140-147.

Haab, T. C., & McConnell, K. E. (2002). *Valuing environmental and natural resources: The econometrics of non-market valuation*. Cheltenham, UK: Edward Elgar.

Hamilton, K., & Atkinson, G. (2006). *Wealth, welfare, and sustainability*. Cheltingham, UK: Edward Elgar.

Hamilton, K., & Bolt, K. (2004). Resource price trends and development prospects. *Portuguese Economic Journal, 3*, 85-97.

Hamilton, K., & Clemens, M. (1999). Genuine savings rates in developing countries. *World Bank Economic Review, 13*, 333-356.

Hamilton, K., & Ruta, G. (2009). Wealth accounting, exhaustible resources and social welfare. *Environment and Resource Economics, 42*, 53-64.

Hartwick, J. M. (1977). Intergenerational equity and the investing of rents from exhaustible resources. *American Economic Review, 66*, 272-274.

Hartwick, J. M. (1995). Constant consumption paths in open economies with exhaustible resources. *Review of International Economics, 3*, 275-283.

Hornborg, A. (2006). Footprints in the cotton fields: The industrial revolution as time-space appropriation and environmental load displacement. *Ecological Economics, 59*, 74-81.

Hornborg, A. (2009). Challenges in conceptualizing environmental load displacement and ecologically unequal exchange in the world-system. *International Journal of Comparative Sociology, 50*, 237-262.

Houghton, R. A., Lawrence, K. T., Hackler, J. L., & Brown, S. (2001). The spatial distribution of forest biomass in the Brazilian Amazon: A comparison of estimates. *Global Change Biology, 7*, 731-746.

Howse, R. (2002). The appellate body rulings in the shrimp/turtle case: A new legal baseline for the trade and environmental debate. *Columbia Journal of Environmental Law, 27*, 1-23.

Hoyos, D. (2010). The state of the art of environmental valuation with discrete choice experiments. *Ecological Economics*, *69*, 1595-1603.

Instituto Nacional de Pesquisas Espaciais. (2009). *Sistema DITER*. Retrieved from http://www.inpe.br/

Isham, J., Woolcock, M., Pritchett, L., & Busby, G. (2005). The varieties of resource experience: Natural resource export structures and the political economy of economic growth. *World Bank Economic Review, 19*(2), 141-174.

Jayadevappa, R., & Chhatre, S. (2000). International trade and environmental quality: A survey. *Ecological Economics, 32*, 175-194.

Kaimowitz, D., Mertens, B., Wunder, S., & Pacheco, P. (2004). *Hamburger connection fuels Amazon destruction*. Jakarta, Indonesia: Center for International Forestry Research. Retrieved from http://www.veganimal.info/IMG/pdf/rapportCIFORamazon-2.pdf

Kaplinsky, R., McCormick, D., & Morris, M. (2007). *The impact of China on Sub-Saharan Africa* (Institute of Development Studies Working Paper 291). Retrieved from http://www.hubrural.org/pdf/ids_wp291_impact_china_on_ssa.pdf

Leite, C., & Weidmann, J. (2002). Does mother nature corrupt? Natural resources, corruption, and economic growth. In G. Abed & S. Gupta (Eds.), *Governance, corruption, and economic performance* (pp. 159-196). Washington, DC: IMF.

Lindert, P. H., & Williamson, J. G. (2003). Does globalisation make the world more unequal? In A. M. Taylor & J. G. Williamson (Eds.), *Globalization in historical perspective* (pp. 227-276). Cambridge, MA: NBER.

Lopez, R. (1994). The environment as a factor of production: The effects of economic growth and the trade liberalization. *Journal of Environmental Economics and Management, 27*, 163-184.

Malhi, Y., Roberts, J. T., Betts, R. A., Killeen, T. J., Li, W., & Nobre, C. A. (2008). Climate change, deforestation, and the fate of the Amazon. *Science, 319*(5860), 169.

Margolis, M. (2009). Unprotected resources and voracious world markets: A proof of losses in North–South Trade. *Resource and Energy Economics, 31*(1), 50-57.

Margulis, S. (2003). *Causes of deforestation of the Brazilian Amazon*. Washington, DC: World Bank.

Martinez-Alier, J. (1993). Distributional obstacles to international environmental policy: The failures at Rio and prospects after Rio. *Environmental Values, 2*, 97-124.

Martinez-Alier, J. (1995). The environment as a luxury or "too poor to be green"? *Ecological Economics, 13*(1), 1-10.

Martinez-Alier, J., Munda, G., & O'Neill, J. (1999). Commensurability and compensability in ecological economics. In M. O'Connor & C. Spash (Eds.), *Valuation and the environment: Theory, methods, and practice* (pp. 37-58). Cheltenham, UK: Edward Elgar.

Morrison, W. M. (2008). *China's economic conditions*. Washington, DC: Library of Congress Congressional Research Service. Retrieved from http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA511980&Location=U2&doc=GetTRDoc.pdf

Morton, D. C., DeFries, R. S., Shimabukuro, Y. E., Anderson, L. O., Arai, E., del Bon Espirito-Santo, F., . . . Morisette, J. (2006). Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. *Proceedings of the National Academy of Sciences, 103*, 14637-14641.

Muradian, R., & Martinez-Alier, J. (2001). Trade and the environment: From a southern perspective. *Ecological Economics, 36*, 281-297.

Muradian, R., O'Connor, M., & Martinez-Alier, J. (2002). Embodied pollution in trade: Estimating the "environmental load displacement" of industrialised countries. *Ecological Economics, 41*, 51-67.

Naylor, R., Steinfeld, H., Falcon, W., Galloway, J., Smil, V., Bradford, E., . . . Mooney, H. (2005). Losing the links between livestock and land. *Science, 310*, 1621-1622.

Nepstad, D. C., Stickler, C. M., & Almeida, O. T. (2006). Globalization of the Amazon soy and beef industries: Opportunities for conservation. *Conservation Biology, 20*, 1595-1603.

Neumayer, E. (2000). Resource accounting in measures of unsustainability: Challenging the World Bank's conclusions. *Environmental and Resource Economics, 15*, 257-278.

Neumayer, E. (2003). *Weak versus strong sustainability: Exploring the limits of two opposing paradigms* (2nd ed.). Chelthenham, UK: Edward Elgar.

O'Neill, J. (1997a). Managing without prices: The monetary valuation of biodiversity. *Ambio, 26*, 546-550.

O'Neill, J. (1997b). Value pluralism, incommensurability, and institutions. In J. Foster (Ed.), *Valuing nature? Ethics, economics, and the environment* (pp. 75-88). New York, NY: Routledge.

Pearce, D. W., & Atkinson, G. (1993). Capital theory and the measurement of sustainable development: An indicator of weak sustainability. *Ecological Economics, 8*, 103-108.

Peters, C. M., Gentry, A. H., & Mendelsohn, R. O. (1989). Valuation of an Amazonian rainforest. *Nature, 339*, 655-656.

Pethig, R. (1976). Pollution, welfare, and environmental policy in the theory of comparative advantage. *Journal of Environment Economics and Management, 2*, 160-169.

Pezzey, J. C. (1992). *Sustainable development concepts: An economic analysis* (World Bank Environment Paper No. 2). Washington, DC: World Bank. Retrieved from http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/1999/10/21/000178830_98101911160728/Rendered/PDF/multi_page.pdf

Proops, J. L., Atkinson, G., Schlotheim, B. F., & Simon, S. (1999). International trade and the sustainability footprint: A practical criterion for its assessment. *Ecological Economics, 28*(1), 75-97.

Redding, S. (1999). Dynamic comparative advantage and the welfare effects of trade. *Oxford Economic Papers, 51*, 15-39.

Reisen, H. (2007). *Is China actually helping improve debt sustainability in Africa?* (G24, Policy Brief No. 9). Retrieved from http://www.g24.org/pbno9.pdf

Renard, M-F. (2011). *China's trade and FDI in Africa* (African Development Bank Working Paper No. 126). Tunis, Tunisia: African Development Bank. Retrieved from http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/WPS%20No%20126%20China%E2%80%99s%20trade%20and%20FDI%20in%20Africa.pdf

Ruffin, R. J. (2002). David Ricardo's discovery of comparative advantage. *History of Political Economy, 34*, 728-748.

Russi, D., Gonzalez-Martinez, A. C., Silva-Macher, J. C., Giljum, S., Martinez-Alier, J., & Vallejo, M. C. (2008). Material flows in Latin America: A comparative analysis of Chile, Ecuador, Mexico, and Peru, 1980-2000. *Journal of Industrial Ecology, 12*(5/6), 704-720.

Sachs, J. D., & Warner, A. M. (1999). The big push, natural resource booms and growth. *Journal of Development Economics, 59*, 43-76.

Sefton, J. A., & Weale, M. R. (1996). The net national product and exhaustible resources: The effects of foreign trade. *Journal of Public Economics, 61*, 21-47.

Soares-Filho, B. S., Nepstad, D., Curran, L., Cerqueira, G. C., Garcia, R. A., Ramos, C. A., . . . Schlesinger, P. (2006). Modeling conservation in the Amazon basin. *Nature, 440*, 520-523.

Spash, C. L. (1993). Economics, ethics, and long-term environmental damages. *Environmental Ethics, 15*(2), 117-132.

Srinivasan, U. T., Carey, P. C., Hallstein, E., Higgins, P. A., Kerr, A. C., & Koteen, L. E. (2008). The debt of nations and the distribution of ecological impacts from human activities. *Proceedings of the National Academy of Sciences, 105*, 1768-1773.

Stern, N. (2006). *Stern review on the economics of climate change*. London: U.K. Treasury.

Stiglitz, J. E. (2009). GDP fetishism. *Economists' Voice, 6*(8), 5-7.

Stiglitz, J. E., Sen, A., & Fitoussi, J.-P. (2009). *Report by the commission on the measurement of economic performance and social progress*. Paris, France: Commission on the measurement of economic performance and social progress. Retrieved from http://www.citymaking.com/wp-content/uploads/2010/01/19784660-Happiness-and-Measuring-Economic-Progress-by-Joseph-Stiglitz.pdf

Sunstein, C. R. (1993). Incommensurability and valuation in law. *Michigan Law Review, 92*, 779-862.

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

Torras, M. (2000). The total economic value of Amazonian deforestation, 1978-1993. *Ecological Economics, 33*, 283-297.

Torras, M. (2003). An ecological footprint approach to external debt relief. *World Development, 31*, 2161-2171.

Tull, D. M. (2006). China's engagement in Africa: Scope, significance and consequences. *Journal of Modern African Studies, 44*, 459-479.

Tyler, Z. (2007). Saving fisheries on the high seas: The use of trade sanctions to force compliance with multilateral fisheries agreements. *Tulane Environmental Law Journal, 20*, 43-96.

Vallejo, M. C. (2010). Biophysical structure of the Ecuadorian economy, foreign trade, and policy implications. *Ecological Economics, 70*, 159-169.

Van den Bergh, J. C. J. M., & Verbruggen, H. (1999). Spatial sustainability, trade, and indicators: An evaluation of the ecological footprint. *Ecological Economics*, *29*(1), 61-72.

van Dijk, M. (2009). *The new presence of China in Africa*. Amsterdam, Netherlands: Amsterdam University Press.

Vincent, J. R. (1997). Resource depletion and economic sustainability in Malaysia. *Environment and Development Economics, 2*, 19-37.

Vincent, J. R., Panayotou, T., & Hartwick, J. M. (1997). Resource depletion and sustainability in small open economies. *Journal of Environmental Economics and Management, 33*, 274-286.

Waye, V. (2008). Carbon footprints, food miles and the Australian wine industry. *Melbourne Journal International Law, 9*, 271-300.

Weisz, H. (2007). Combining social metabolism and input-output analyses to account for ecologically unequal trade. In A. Hornborg, J. R. McNeill, & J. Martinez-Alier (Eds.), *Rethinking environmental history: World-system history and global environmental change* (pp. 289-306). Lantham, MD: Altamira.

Weitzman, M. L. (1997). Sustainability and technical progress. *Scandinavian Journal of Economics, 99*(1), 1-13.

World Bank. (2006) *Where is the wealth of nations?* Washington, DC: Author.

World Bank. (2010). *World development indicators*. Retrieved from http://data.worldbank.org/

World Bank. (2011). *The changing wealth of nations*. Washington, DC: Author.

Zafar, A. (2007). The growing relationship between China and Sub-Saharian Africa: Macroeconomic, trade, investment, and aid Links. *World Bank Research Observer, 22*(1), 103-130.

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