China, the U.S., and Sustainability:
Perspectives Based on Comprehensive Wealth

by

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I. Introduction

Policy analysts and policy makers are keenly interested in whether the performance of national economies is consistent with some notion of "sustainability." This reflects growing concerns about environmental quality and about the depletion of oil reserves and other natural resource stocks. Economists and natural scientists have offered several notions of sustainability. An especially important notion – and the one on which this paper focuses – is defined with reference to human well-being. This notion of sustainability is achieved if the current generation leaves the next one with the capacity to enjoy the same or higher quality of life. Standard measures in the national income accounts – such as changes in per-capita GDP – may offer hints of whether a nation meets this sustainability criterion, but as is well known these measures do not fully capture many important contributors to well-being, such as the changes in the stocks of natural capital or in environmental quality.

The issue of sustainability seems especially relevant to China today. Although estimates vary, per-capita GDP in China appears to have grown at an annual rate of over eight percent over the past 15 years.[1] In terms of marketed goods and services, the nation appears to be making extremely good progress. At the same time, China has accomplished this GDP growth through significant reductions in its natural resource base. According to China's State Forestry Administration, itinerant farming has contributed to soil erosion on a large scale, with desert expanding at a rate of 10,400 square kilometers per year. China's cities rank among the world's worst for air pollution, and all of China's major waterways are classified as "severely polluted" by the World Resources Institute. This loss of natural

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[1] China's official inflation estimates are lower than estimates from other sources (see, for example, Young (2003), lending to uncertainty as to real GDP growth rates.

capital offsets the positive contribution to the productive base from investments in reproducible capital. As a result, it is not immediately clear whether the China's *overall* productive base is rising or even being maintained. As discussed below, the overall productive base is intimately connected to the ability of the nation to generate goods and services and thus maintain living standards – which is at the heart of our notion of sustainability. Furthermore, China's rapid GDP growth has come at considerable cost in terms of environmental quality. Is per-capita well-being sustainable, given the losses of natural capital and environmental quality?

The sustainability issue also applies to the U.S., but perhaps in a different way. A growing share of the U.S. capital base is owned by foreigners. The sustainability of well-being to U.S. residents is closely connected to the changes in per-capita wealth owned by these residents. Is per-capita wealth of U.S. residents rising and, if so, at what rate?

This paper addresses these and other questions. Our overall objective is to shed light on on whether China and the U.S. are meeting a sustainability criterion. It can be shown (e.g., Arrow *et al.* 2004; see below) that, under a wide set of circumstances, intergenerational well-being is sustainable during a period of time if and only if a comprehensive measure of wealth per capita is non-declining during that same period. This comprehensive wealth measure encompasses a wider range of productive assets than those in traditional national accounts. It embraces not only reproducible capital but also human capital and many commercial forms of natural capital. In addition, the focus on wealth directs attention to the entire intertemporal stream of goods and services implied by today's assets, rather than the current flow of income.

This effort is in the general category of comprehensive wealth accounting. Some of the most important advances in such accounting have been made in recent years by Kirk Hamilton and his collaborators at the World Bank. Hamilton and Clemens (1999) explored whether comprehensive wealth is rising or falling in various developing countries. Arrow *et al.* (2005) built on the World Bank's framework by incorporating technological change and considering population growth. In *Where Is the Wealth of Nations?* (World Bank, 2006), a World Bank team headed by Hamilton provides assessments of changes in comprehensive wealth for nearly every nation of the world.

The present paper aims to advance comprehensive wealth accounting in several ways. First, we offer a more theoretically consistent approach to valuing natural resources. This includes attention to how future changes in natural resource prices can influence comprehensive wealth measured today. This is especially important in regard to reserves of crude petroleum. Second, we offer an improved approach to measuring changes in human capital. While prior work used education expenditure as a proxy for the change in human capital, we employ a measure based on estimates of changes in educational attainment. Third, we explicitly distinguish between domestic and foreign holdings of a nation's capital. Fourth, we introduce an improved treatment of changes in wealth connected with environmental damages associated with climate change.[2]

The paper is organized as follows. The next section lays out the main elements of our analytical framework. Section III then applies the framework to examine the changes in per-capita comprehensive wealth in China and the U.S. over the period 1995-2000. Section IV offers conclusions and suggests directions for future work.

II. Methodology

A. A Sustainability Criterion

Researchers have offered a great many definitions of sustainability, as evidenced by Pezzey's (1992) survey of the various notions. Our sustainability requirement focuses on intertemporal welfare. (See Arrow *et. al.* [2004, pp. 150-154] for discussion and references). According to this approach, the (intertemporal) welfare of any one generation is determined not merely by its utility for current consumption but also for the care it has

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[2] Human well-being depends critically on levels of health. Recent work by Nordhaus (2002) and Cutler and Richardson (1997) suggests that changes in health can have a value comparable to changes in GDP or other traditional income measures. In the near future we plan to integrate health in the comprehensive wealth framework described in this paper.

for future generations. We let V denote intertemporal welfare. One possible expression for V is:

$$V(t) = \int_t^\infty e^{-\delta t} U[c(u)]du \tag{1}$$

where t is time, δ is the subjective rate of discount of utility (time preference), U is satisfaction or *felicity* at any moment of time, and c is an aggregate vector of different kinds of consumption. The c vector includes not only marketed goods but also amenity values of natural resources, and various dimensions of health. The criterion of sustainability is that V is non-decreasing:

$$dV / dt \geq 0. \tag{2}$$

The possibilities for consumption are determined by an economy's *productive base*, an index of the quantities available of a number of types of capital. The capital assets include (1) manufactured capital goods, referred to as "reproducible capital," (2) human capital, the productive capacity inhering in human beings and acquired through education,[3] and (3) various kinds of natural capital. Natural capital includes land and various mineral resources.

Production of new goods takes place according to a technology which relates the use of various forms of capital to outputs. For simplicity, and again in accord with standard models of economic growth, this analytical framework assumes there is one output, which can either be consumed or added to reproducible capital. Natural resources may be nonrenewable, as with minerals, or renewable, as with forests. In the former case, the stock of the natural resource in any period is reduced by the quantity extracted (the flow) in that period. In the latter, the stock is increased by its natural rate of growth as well

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[3] We follow the general precedent of empirical studies in growth economics in measuring human capital by some function of the embodied years of education (see, e.g., Klenow and Rodríguez-Clare [1997], and Mankiw [1992].) Of course, studies in human capital have also considered human capital as being formed by experience (e.g., Becker, Philipson, and Soares [2005]), but the data we draw on have not made use of this or other refinements.

as being reduced by the flow used. The rate of change in the stock of a particular kind of capital is called the *investment* in that kind of capital. Investment in nonrenwable natural resources is necessarily negative.

The output generated by the productive base divides between consumption goods and services and investment in reproducible capital. We assume that allocation rules (which may include functions of market prices) determine the allocation of output between consumption and investment, and that the allocation system is *autonomous*, by which we mean that V is not an explicit function of time. Hence the stocks of the different kinds of capital in the next period are determined by the stocks in the present period and the (fixed) allocation rules.

By proceeding from period to period this way, the entire future course of capital stocks and therefore of flows of investment (by following the allocation rules) is determined.[4] Given the stocks of the different kinds of capital, K_i $(i = 1,\ldots n)$ at some time t, the values of K_t and consumption c are determined at all future times $u \geq t$. Hence $U[c(u)]$ is determined for all $u \geq t$, and, from (1), $V(t)$ is determined as well. Hence we can write:

$$V(t) = V[K_1(t), K_2(t), \ldots, K_n(t)]. \tag{3}$$

Therefore, from (2), sustainability requires that

$$dV/dt \;=\; \sum_{i=1}^{n} (\partial V/\partial K_i)(dK_i/dt) > 0. \tag{4}$$

The theory we are invoking here does not require that intergenerational well-being, V, have the functional form given in equation (1). Let $q_i \equiv \partial V/\partial K_i$ and $I \equiv dK_i/dt$. The variable q_i is the marginal contribution of the i^{th} type of capital to intertemporal welfare,

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[4] We abstract from uncertainty. For the purposes of determining sustainability over a short period of time, this is a legitimate approximation. However, for many policy purposes, uncertainty about the future should not be ignored.

and thus may be thought of as the *shadow price* of that kind of capital. I_i is the time derivative of the capital stock K_i or, in the usual terminology, the *investment* in that capital. It follows that

$$dV/dt = \sum_{i=1}^{n} q_i I_i. \tag{5}$$

Thus, *dV/dt* is the value of the new investments in different kinds of capital evaluated at the shadow prices. This suggests an interpretation of *dV/dt* as the change in wealth evaluated at constant prices, i.e., the change in real wealth. Since we are including all forms of wealth, including natural resources, we refer to this as the change in *comprehensive* wealth.[5] Hence, from (4), the criterion for sustainability is precisely that real wealth is increasing.

The shadow prices are the prices that would prevail if all commodities were traded in competitive markets and if there were perfect foresight. Thus the shadow price for a nonrenewable resource such as oil is the discounted value of future use. It is therefore the price at which the owner of the well would be indifferent between selling the oil now and holding it for future sale. More precisely, the shadow price is the difference between the sales price of the oil and the cost of its extraction; it is the price paid for the *scarcity* of the resource.

The shadow prices are stated above in units of utility per unit capital. In view of the arbitrariness in the choice of units for utility, it is useful to employ a different *numéraire*; a natural choice is the aggregate commodity which can be used for either consumption or reproducible capital. This is the same technique as is used in ordinary price indices. Let reproducible capital be given the index 1 in the enumeration of types of capital. Then define the shadow prices of the different kinds of capital measured in terms of reproducible capital,

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[5] In a similar spirit, Hamilton and Clemens (1999) introduced the term “genuine savings,” where the modifier “genuine” distinguishes more comprehensive savings (savings that contributes to increased natural resource stocks as well as reproducible capital) from narrower, standard notions of savings.

$$p_i = q_i / q_1, \quad (i = 1, \ldots n), \tag{6}$$

and the change in comprehensive wealth in the same terms:

$$dW / dt = \sum_{i=1}^{n} p_i I_i \tag{7}$$

Here $p_1 = 1$, from (6). Hence sustainability requires that

$$dW / dt > 0. \tag{8}$$

The formalism used here permits a measure of comprehensive wealth, as well as of the change in comprehensive wealth. In the notation already used,

$$W = \sum_{i=1}^{n} p_i K_i . \tag{9}$$

This explicit measure of comprehensive wealth is designed to replace the rough approximations used in Arrow *et. al.* (2004, Table 1 and Note, p. 163).

B. Measuring Investments and Determining Shadow Prices

1. Natural Capital

To value the changes in natural capital, we need to consider both the net investment (DK) and the shadow price to apply to that investment. The net investment in a nonrenewable resource is simply the negative of the amount used up. The shadow price is related to the rental value of the resource. As is well known since the classical analysis of Hotelling (see, e.g., Dasgupta and Heal [1979]), in a competitive setting the rental value of a nonrenewable resource should rise at the rate of interest (the marginal productivity of capital). If we abstract from externalities associated with use of the resource, then the rental value will correspond to the resource's shadow price.

For renewable resources, such as forests, the shadow price is again the rental value (price less cost of cutting), but the net investment equals the increase in the forests due to natural growth and planting less the amount used up.

2. Capital Gains in Nonrenewable Resources

To the extent that the rental value of a nonrenewable resource rises through time, owners of the resource stock should expect to receive capital gains. Similarly, future consumers should expect to pay higher real prices. Other things equal, this implies a reduction in real wealth. Thus the impacts on real wealth of a given nation's residents will depend on the extent to which the residents own (and sell) or consume (purchase) the resource in question. In the empirical application below, we account for these wealth impacts. It appears that these impacts have not been addressed in any of the prior literature.[6] It may be noted that in a closed economy there is no need to adjust wealth for capital gains or losses, since the future gains to owners will be exactly offset by the losses to future consumers

For each country, the capital gain is equal to the stock of the resource times the rate of increase of the shadow price (i.e., the rate of interest). Summing over all countries gives the total capital gains to that resource. The corresponding capital losses by purchasers must be equal to this sum. In principle, it should be allocated among individual countries in accordance with their future purchases of oil. In the empirical application below we have approximated by giving each country a capital loss equal to total capital losses to consumer times that country's share of current consumption.

3. Human Capital

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[6] In particular, Arrow *et. al.* (2004) failed to take account of the capital gains to countries with large oil reserves. As a result, that study might have understated the sustainability of Middle East countries (see Table 2, p. 163, and discussion on p. 165).

We follow the methods introduced by Klenow and Rodríguez-Clare (1997), which builds on the earlier work of Mincer. That is, it is assumed that education is taken to earn a market rate of interest for the period of education. Assuming, as a first approximation, a steady state, the amount of human capital per worker is proportional to $e^{\rho A}$, where ρ is the appropriate rate of interest (taken to be 8 ½% per annum) and A is the average number of years of educational attainment.

The stock of human capital, then, is the human capital per worker multiplied by the number of workers. This quantity is adjusted for mortality during the working life.

We assume that the labor market is sufficiently competitive that the marginal productivity of human capital is equal to its shadow price and also equal to the real wage. Hence the shadow price of human capital is equal to the total real wage bill divided by the stock of human capital.

4. Technological Change

In the presence of technological change, the rate of growth of wealth is increased beyond that indicated by the growth in the stocks of individual kinds of capital, as displayed in (8).[7]

We follow the treatment of Arrow *et. al.* [2004, fn. 7, pp. 153-4], adjusted to a different specification of the production function. Arrow *et. al.* assumed that output is a function of reproducible capital and labor, so the elasticity of output with respect to capital was assumed to be a constant α less than one. We now follow Klenow and Rodríguez-Clare (1997, 2005) in making output a function of two kinds of capital, reproducible and human. Thus the elasticity of output with respect to all forms of capital is now one. Hence, from Arrow *et. al.* (2004, fn. 7), where α is set equal to 1, the adjustment to the rate of growth of real wealth is obtained by adding the Hicks-neutral rate of technological progress to the rate of growth of the aggregate of other forms of capital.

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[7] Another way of looking at this is to consider the stock of knowledge as one form of capital. Then the growth in knowledge will be one form of investment, so that (8) does not have to be altered.

5. Population

Again we follow the usage of Arrow *et. al.* (2004, pp. 152-3). If population is changing, then the appropriate measure of sustainability is that real wealth *per capita* should be growing. From (9) and (10), the sustainability criterion for a changing population is that

$$(dW/dt)/W - \pi > 0, \tag{10}$$

where π is the rate of growth of population (assumed to be exogenous).

6. Climate Change and Other Environmental Externalities

Our aim is to subtract from growth in comprehensive wealth the damages caused to a country by anthropegenic climate warming and other pollution externalities. Our approach differs from that in Hamilton and Clemens (1999) and used in Arrow *et. al.* (2004, Table 1, p. 163), which assume that the climate change damages to a given country depend entirely on that country's carbon dioxide emissions. In contrast, our approach considers global emissions (rather than just those of the U.S. and China) over the time-interval of interest, calculates the estimated damages from these emissions (now and in the future), and attributes a share of the global damages to the U.S. and China. The estimated damages are then subtracted from other investments in the calculation of comprehensive investment.[8]

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[8] This adjustment of the investment flows for externalities is an approximation. A more refined approach (not taken in this paper) would adjust as well the shadow values of each type of capital to account for the discounted value of the environmental damages (to the country owning the capital) caused by the use of that capital. Thus the shadow price of reproducible capital (including, in principle, durable consumer goods such as automobiles) would be reduced by the economic value of the health and disamenity costs imposed by particulate matter, sulfur dioxide, and other forms of pollution emitted, as well, of course, as the effects on global warming. If, over a given time-interval the amount of pollution increases, leading to greater environmental damages, the values of capital would be reduced to account for this change.

III. Empirical Application

In this section we estimate comprehensive wealth for China and the U.S. in 1995 and 2000. As mentioned, comprehensive wealth accounts for the values of natural, human, and reproducible capital.

Our empirical application proceeds in two main steps. First, we evaluate the levels and changes in various stocks of capital over the 1995-2000 time-interval. We then consider the change in wealth on a per-capita basis, and make an adjustment for technological change.

A. Levels and Changes in Capital Stocks

1. Natural Capital

Natural capital includes exhaustible energy and mineral resources as well as renewable forest and land resources. We focus on the economically most important types of natural capital, to the extent that data are available.

a. Oil and Natural Gas

As indicated in Section II.B.1, for nonrenewable resources the appropriate price to apply to the change in the capital stock is the scarcity rent on the resource. For several nonrenwable resources – particularly those with remaining reserves large enough to last more than 100 years at current rates of extraction – the estimated reserves are so large as to make the scarcity rents negligible. We therefore ignored nonrenewable resources whose remaining reserves could provide for over 100 years of use at current extraction rates. Hard and soft coal, bauxite, and iron ore were all ignored for this reason. We focus instead on oil, natural gas, other metal and mineral resources, forests, and land.

Not all of the stock of oil or natural gas is close enough to the surface or in a form that it is likely to be extracted given current technology and prices. To measure this, petroleum engineers use two categories: proved reserves and unproved reserves. Proved reserves are the stock of the resource that is estimated to be commercially recoverable under the current economic conditions, technology, and government regulation. Unproved reserves are reserves that are unlikely to be commercially recoverable under current conditions.

In recent years, changing prices and new operating methods have allowed petroleum engineers to increase the stock of these energy resources that they characterize as proved reserves. In fact, from 1995 to 2000, the proved reserves of oil in the world increased by 8.7 percent to 1,115.8 billion barrels (even after more than 130 billion barrels were extracted). The proved reserves of natural gas increased even more rapidly at 12.1 percent over this same period. These increases are not only the result of changing economic conditions; they also reflect annual discoveries of oil and natural gas.

To calculate consistently the changes in the resource base, we start with a recent estimate of the proved reserves for the resource and then to back out, using production data, the stock of the resource in prior years. This irons out the impact of new discoveries and emphasizes the idea that, whatever the true global stock of reserves, this stock is diminished by the amount of extraction. Thus, given the estimated stock of a nonrenewable resource at the end of year *t*, the stock at the end of year *t*-1 is given by

$$K_{t-1} = K_t + X_t \tag{11}$$

where K_t and X_t represent proven reserves and extraction, respectively, in period *t.* The 2004 proved reserves and production data for oil and natural gas was obtained from the *BP Statistical Review of World* Energy (2005). We take the 2004 proved reserve and then add the quantity produced during the year to calculate the 2003 stock. We repeat this method to calculate the stock in 1995 and 2000.

To value the stock of a particular resource, we use the average unit rent in 1995 and 2000 for each country. This is the difference between the average real price and the average real extraction cost which, as an approximation, we assume reflects the shadow value of the decline in the resource stock. We assume a constant world price during the period, measured as the real average of spot prices over 1995 to 2000. For oil we average the price of four types of crude (Dubai, Brent, Nigerian Forcados, and West Texas Intermediate) and for natural gas we average the price from four sources (US, UK, Japan, and European Union). The extraction costs, obtained from the World Bank (2005), are based on several different studies. For both energy resources, China's extraction costs are not given, so we use 80 percent of the U.S. estimate for oil and the world average for natural gas.

b. Metals and Minerals

We follow the same approach for measuring the stock of metal and mineral resources in each country. The stock of each resource in 2000 and the annual production volumes were assembled from various sources, including the World Bank's *Where is the Wealth of Nations*, USGS, and other sources. As was explained for oil and natural gas, the stock of the resource in the previous year is obtained by deducting the quantity produced during the year.

Average world market price and extraction costs for each resource in each country were obtained from World Bank data (2005). As described above, we use the difference over the period between the average real price and the average real extraction cost to calculate the shadow value (scarcity rent) of one unit of the stock. If for any year between 1995-2000 the world market price was below the country's extraction cost, we eliminated the metal or mineral from the calculus. Our assumption in these cases was again that the scarcity rent was negligible since the world price was below extraction cost. As a result, we eliminated gold, nickel, tin, silver, and zinc from the analysis. If, for all years in 1995-2000, price was greater than cost, we averaged the difference between annual real price and annual real extraction cost, adjusted to year 2000 dollars, to obtain our measure of the average unit rent for the period 1995-2000.

c. Forests

While globally the area of forest cover continues to decline (mainly due to conversion to agriculture – see FAO [2005]), forest area and forest stock increased between 1995 and 2000 in both the US and China. This increase is largely due to afforestation on productive plantations. China and the US account for 42 percent of the world's area of productive plantations. Over the interval 2000-2005, China's increase in forest area was the largest in the world, increasing by 4,058 hectares per year and dwarfing the gains in the US (the 4th largest net gainer at 159 hectares per year).

We obtained total cubic meters of commercially available forests from the Food and Agriculture Organization (FAO) Forestry Resources Assessment (FRA) (FAO 2005). These data include volumes of growing stock of forests and other wooded resources in 1990, 2000, and 2005, and designate the amount of total stock that is commercially available. The difference in stock from one year to the next is assumed to be "produced" (if negative) or "afforested" (if positive). Subject to all the caveats that can be justifiably raised regarding the comparability of cross-country statistics, the stock would appear to have increased in the U.S. and in China during 1995-2000.

For the accounting (shadow) price on forests, we used the rental value. The rental value was calculated as the weighted average market price of the types of wood minus the extraction costs. Extraction costs, specific to each country, were obtained from the World Bank's Adjusted Net Savings data. The resulting accounting price is $52 per cubic meter for the US, and $30 per cubic meter for China.

Note that this differs significantly from the previous World Bank method, where all estimates of commercially valuable area, stock per hectare, and net annual increase were independently estimated. Because the volume of commercial stock was included in FAO Forest Resources Assessment, we eliminated these "judgment calls" (but were therefore forced to use region-specific information in some cases). Because of the recent reversal in the historical trend of deforestation in these two nations, we credited them with the value of its afforested stock. In future calculations we would like to include afforestation costs, which can be significant expenses.

d. Land

Values for land include non-timber forest resources, protected areas, cropland, and pastureland. We obtained these values using information from the World Bank, as presented in *Where is the Wealth of Nations?* Briefly, the World Bank uses two studies to estimate the value of non-timber forest resources. One-tenth of forested area is considered "accessible" to these kinds of non-extractive activities, and is assigned a value of $190 per hectare in developed countries and $145 per hectare in developing nations. The value of cropland is set equal to the present discounted value of land rents, which are based on a percentage of estimated production revenue for an array of crops sold at world market prices. The total land rent is the area-weighted average of rents from major crops. Pastureland is valued as the opportunity cost of preserving land for grazing. Returns are calculated assuming a fixed proportion of value to output (returns are estimated at 45% of output), where output is based on production of beef, lamb, milk, and wool sold at world market prices. The minimum value of protected areas is the opportunity cost of preservation, thus the value is the lower of per-hectare returns to pastureland and cropland, applied to the area under official protection. All benefits were applied over a 25-year time horizon at a 4% discount rate.

Summing across all types of rural land, in 1995 the US had a total land value of $1.8 trillion, compared to China's $2.0 trillion. We do not attempt to include the value of urban land. We do not have data to calculate the dynamics of land use change in the period 1995-2000.

e. Results for Natural Capital

Table 1 displays the estimated changes in natural capital, both in quantities and in value terms. In both the U.S. and China, the reductions in oil and natural gas are far greater (in value terms) that those of copper, lead, or phosphate. The increased value of forest offsets about half of the lost value from oil and gas depletion. The reduction in the value of the natural capital stock is about two times larger in the U.S. than in China. However, as a proportion of GDP, the reduction is about five? times larger in China.

2. Human Capital

The value of the stock of human capital is an important component of a country's wealth. To measure the stock of human capital, we use estimates of average educational attainment contained in an unpublished data set provided by Klenow and Rodríguez-Clare. We will refer to this as the "Klenow and Rodríguez-Clare data."[9]

The stock of human capital for an individual, h, is given by

$$h = e^{\rho \bullet A} \tag{12}$$

where ρ is the assumed rate of return on human capital and A is the level of educational attainment. Following Klenow and Rodríguez-Clare (1997), we apply a value of 0.085 for ρ. To find the aggregate stock of human capital, H, we simply multiply h by the population of the county. Rather than use the total population, we exclude children under the age of 17 in the United States and children under the age of 11 in China. These age cut-offs are based on the age at which an individual would reach the average education level in each country and are meant to exclude those who have not yet built up their stock of human capital. It is important to point out that the stock of human capital includes the human capital of those not currently in the labor force. Just because an individual is not currently employed does not mean that he or she has no human capital. The measure of the aggregate human capital stock increases both as the average educational attainment increases and as the population over the selected age cut-off increases.

We now need to find the price of a unit of human capital in order to place a value on the stock. Our method is to calculate the rental price for an employed unit of human capital and then to find the average number of working years remaining for the population

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[9] This data set underlies the estimates reported in Klenow and Rodrguez-Clare (2005).

above the age cut-off. The value of a unit of human capital is the discounted sum of the rental price, *r*, for the average number of working years remaining.

$$P_{K_H} = \int_{t=0}^{years} r e^{-\rho t} dt \tag{13}$$

The rental price of a unit of human capital is simply the country's total wage bill divided by the employed number of human capital units (not the whole human capital stock). The total wage bill in the US is easily obtained from the national income accounts. China's national income accounting method does not report total wages or compensation, so this is calculated from information provided by the *China Statistical Yearbook.* Employment in both countries is obtained from the Klenow and Rodríguez-Clare data. The average rental price per year for a unit of human capital is \$528.11 in China and \$12,807.98 in the U.S.

To calculate the average number of working years remaining for the population over the age cur-off in each country we use data from the World Health Organization Life Tables and the US Census Bureau IDB demographic data. The calculation depends on the age distribution of the population, the age specific force of mortality, and the labor market participation rate (probability of employment) at each age. We assume that the force of mortality and the age-specific probability of employment remain constant over time in these calculations. Individuals over the age of 11 in China have on average 21.7 years of work ahead of them, while individuals over the age of 17 in the U.S. have on average 15.7 years of work ahead of them. This gives one unit of human capital a value of \$6,997 in China and \$139,092 in the U.S.

3. Reproducible Capital

The estimated stock of reproducible capital in the U.S. and China are from the Klenow and Rodríguez-Clare data. Our approach to reproducible capital differs from earlier work by the World Bank and by Arrow *et al.* by accounting for ownership. Some of the stock of reproducible capital in a country is owned by investors outside of that country. Correspondingly, some of the reproducible capital outside a given country is owned by the residents of that country. Our notion of sustainability focuses on the changes in the productive base owned by a given country's residents. Thus it is important to consider changes in a country's net asset position.

In the U.S., net holdings of international assets are reported by the BEA. In developing countries, although capital flows are closely monitored, little work has been done on measuring the accumulated stocks of foreign assets and liabilities. We obtain estimates from a recent paper by Philip Lanea and Gian Maria Milesi-Ferretti (2006) that constructs net holdings of international assets from balance of payments and other IMF data.

4. Oil Capital Gains

Our analysis also departs from earlier work in considering capital gains. While capital gains can apply to any capital asset, these gains can be expected to be especially important for stocks of oil. As the world stock of oil decreases, the scarcity rent will increase. Theory suggests an increase at approximately the rate of interest. A country with oil realizes that oil not yet extracted will be worth more tomorrow than today. For each country or region we multiply the stock of oil not extracted during the time period by the difference between price and extraction costs. To calculate the capital gains, we allow the shadow price of oil to increase by five percent per year over the period 1995-2000. We apply this increase in the shadow price of oil to the initial (year 1995) oil stock. Thus, the overall change in the value of the oil stock is

$$p_{K_t} I_t + \dot{p}_t K_{t-1} \tag{14}$$

where I_t is the change in the stock from period $t-1$ to t and $\dot{p}_t$ is the change in the shadow price over this interval.

Capital gains to countries with oil are paid for by countries that consume oil in terms of higher prices. The world total oil capital gains are distributed as a loss to each country in proportion to the fraction of world total oil consumption. The U.S. accounted for 25.7 percent of world oil consumption during the time period and in this calculation we assume that this remains constant over time. Under this assumption, the U.S. pays for 25.7% of world total oil capital gains.

5. Environmental Capital

The World Bank's Adjusted Net Savings method (World Bank 2002) deducted damages caused by climate change from each national account proportional to that nation's emissions. In other words, the US national account was deducted for the damages caused by the 1.5 billion tons of carbon the US emitted in 2000 (wherever on the planet those damages occurred). The marginal social cost of carbon used in the World Bank method of $25 per metric ton carbon was based on Fankhauser's 1994 paper.

Our method changed both the approach and damage estimates. Current models anticipate unequal global distribution of damages from climate change. Therefore, while the US should be morally responsible for compensating other nations for the damage its emissions cause, it is the damage to US assets that should be deducted from its national accounts. We therefore redistribute the global damages based on recent estimates. Furthermore, we actualize the marginal social cost of carbon based on new estimates.

To determine the portion of global damages due to climate change that the US and China will suffer, we utilize Nordhaus and Boyer's (Nordhaus and Boyer 2000) study, which estimates the impacts of various climate change scenarios on economic sectors. We use the most conservative scenario analyzed, corresponding to a doubling of atmospheric concentrations of CO_2-equivalent gases. This scenario is a standard multimodal assessment in the Intergovernmental Panel on Climate Change Third Assessment Report. The physical results of the "greenhouse effect" from this level of pollution are constrained to a mean surface temperature change of 2.5 degrees Celsuis over the entire terrestrial environment, where temperature change is latitude-dependent to reflect results of general-circulation models.

Based on this likely (but simplified) scenario, Nordhaus and Boyer apportion the damages to each country as follows: The US will suffer losses of 0.45% of its GDP, China 0.22% of its GDP, while the globe will suffer damages of 1.5% of global production. We multiplied each country's expected damage by its GDP in 2000 (from World Development Indicators), and global damage by global GDP in 2000. We then calculated the portion of global damages that each country will suffer. The US will shoulder 9% of global loss, and China 1%. We use this geographically linked method to determine the portion of global loss each country will suffer, and we now need to calculate the loss due to emissions in the period 1995-2000. To do so, we use updated estimates of the social cost of carbon to calculate global losses.

To calculate global losses due to emissions from 1995-2000, we extracted global carbon emissions data from the World Development Indicators (2005). We converted the data from tons CO_2 to tons C equivalent by multiplying the tons of CO_2 by the ratio of the molecular weight of C to CO_2 (12/44). Using a recent survey by Tol (2005) on the range of marginal damage estimates in the literature, we assigned a conservative marginal social cost of $50 per ton carbon. This damage estimate is the mean of all peer reviewed studies analyzed by Tol, and far below the recent estimates by other, more comprehensive studies (see, eg.g. Stern 2006). Global emissions of 31 billion tons from the 5-year period of 1996-2000[10] therefore resulted in global damages of $1,612 billion (in year 2000 dollars).

We multiplied the percentage of global loss that each country will suffer (9.32 percent for the U.S., 0.5 percent for China) by the total global damages calculated above ($1,612 billion) to get the damages suffered by each nation due to its emissions in 1995-2000. As such, the US account was deducted $150.2 billion and China $8.1 billion.

6. Overall Changes in Capital – Comprehensive Investment

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[10] 1995 was dropped such that we consistently use a 5-year period in all calculations

Table 2 consolidates the changes in all of the forms of capital we have considered. In the U.S., the increases in human and reproducible capital far outweigh the reductions in natural capital and the net capital losses associated with rising oil prices. Thus, according to this measure, comprehensive investment – the change in the value of the overall capital stock – is positive. For China, comprehensive investment also appears to be positive. According to the table, the increase in human capital and reproducible capital greatly exceeds the loss from depletion of natural capital.

Table 2 also shows the relative contribution of each form of capital (natural, human, reproducible) and of oil capital losses to the overall change in comprehensive investment. In both countries, the relative impact of natural capital depletion is fairly small. Capital losses associated with rising oil prices have a larger impact on comprehensive investment than the depletion of natural capital. The largest impacts are from increases in human and reproducible capital, which overwhelm the negative contributions of the other elements.

It should be emphasized that a key element of these calculations is the shadow or accounting price applied to each type of capital. These indicate the rate at which one form of capital can substitute for another. If the shadow prices for natural capital, in particular, are too low (high), our results will understate (overstate) the lost wealth from depletion in natural resource stocks.

It should also be noted that these calculations do not account for many health-related elements. We discuss this issue further in Section III.

B. Accounting for Population Growth and Technological Change

We next adjust the changes in comprehensive wealth to account for population growth and technological change. The first column of Table 3 reproduces the growth rate of comprehensive investment given in Table 2. Column 2 indicates the annual population growth rate of the U.S. and China over the interval 1995-2000. Column 3 subtracts this growth rate from the rate in Column 1 to arrive at the per-capita growth rate of comprehensive wealth.

The next columns adjust for technological change, as measured by the rate of growth of total factor productivity. Under the assumptions indicated in Section 2, the appropriate adjustment for technological change is obtained by adding the TFP growth rate from the initially obtained growth rate of per-capita comprehensive wealth. Column 5 provides the adjusted rate.

The numbers in column 5 are our ultimate indicators of whether the sustainability criterion is met. According to our calculations, both countries satisfy the criterion, as per-capital comprehensive wealth is growing. (Sensitivity analysis to be offered in next version.) In the U.S., TFP growth (of 1.48 percent) accounts for about 80 percent of the estimated 1.86 percent growth rate of comprehensive wealth. China displays even faster growth of comprehensive wealth – a rate of over five percent. In the case of China, technological change accounts for about half of this fast growth.

When we initiated this study, we were motivated by a concern about the rapid rate of natural resource depletion in China, as well as the continued and extensive levels of air and water pollution. We sought to gain a better sense as to whether, overall, China’s recent economic experience is conducive to higher or lower standards of living for future generations. Although this study is incomplete, it suggests that China’s very high rates of investment in reproducible capital and human capital, along with a relatively high rate of technological progress, might well outweigh the costs from natural resource depletion and environmental damage. These interpretations must be very tentative, however. It is important to keep in mind that our results do not capture important environmental and health impacts. Currently, the shadow prices for natural capital do not incorporate beneficial externalities from such capital. Thus, the present analysis could well understate the welfare cost from depletion of such capital. Similarly, the shadow prices for reproducible capital do not yet include the environmental and health impacts from such capital. The bias from this latter omission is not immediately clear. To the extent that newer capital is associated with increased emissions and damages to health, our assessment biases upward the change in comprehensive wealth. On the other hand, to the extent that new capital is associated with improvements in health, the omission biases the wealth change in the opposite direction.

IV. Conclusions

This paper has presented and applied a framework for determining whether a given nation satisfies a reasonable criterion for sustainability. We define sustainability in terms of the capacity to provide well-being to future generations. The principal indicator of this capacity is a comprehensive measure of wealth – one that includes both marketed and non-marketed assets. The sustainability criterion is satisfied if this comprehensive measure of wealth is increasing on a per-capita basis.

Our framework follows Arrow *et al.* (2005) in integrating population growth and technological change in the analysis of comprehensive wealth. It offers further methodological improvements by accounting for capital gains, providing a closer assessment of changes in human capital, and addressing potential damages from climate change.

Our initial application of this framework to China and the U.S. suggests that both nations are meeting the sustainability criterion. In the U.S., increases in human capital and (to a lesser extent) reproducible capital significantly outweigh the adverse wealth effects from natural resource depletion and higher oil prices. In China, investments in reproducible capital contribute the most to increases in genuine wealth, although increases in human capital and (predicted) technological progress also play a significant role. Importantly, China's depletion of natural resources, though very significant, do not have nearly as large an impact on wealth as do the contributions from investments in reproducible and human capital.

These results must be viewed as preliminary and tentative. We have not yet incorporated many important health impacts, which could significantly change the picture. Between 1995 and 2000 life expectancy at birth for the population as a whole increased by 1.6 years in China and 1.2 years in the USA. In China the gain was in large measure a reflection of reductions in the under-5 mortality rate (from 46 to 40 deaths per 1000 births), while in the USA the major factor would appear to have been reductions in mortality caused by cardiovascular disease. A commonly accepted method for valuing reductions in mortality rates in terms of income is to estimate differences in wages that can be attributed to differences in the risk of death in various occupations. Measured thus, the gains would appear to be very large. For example, Nordhaus (2002) has estimated that during the last 100 years the economic gains in the US from increases in life expectancy were comparable to the growth in non-health consumption goods and services. We conjecture from that work that the contribution of improvements in health to the accumulation of comprehensive wealth could be substantial. In future work we intend to estimate that contribution by appealing to a range of approaches to the value of improvements in the health and longevity.

Although ignoring improvements in health biases downward our estimated increases in comprehensive wealth in China and the US, our neglect of a wide range of losses caused by environmental degradataion (e.g., soil loss, water stress, increases in atmospheric pollutants) implies the opposite bias.[11] In future work we hope to take account of changes in a wider range of natural capital stocks.

The estimates we have offered in Table 3 are marred also by the considerable uncertainties that surround the values of the shadow prices employed here, which determine the rates of convertibility across types of capital. Large uncertainties surround technological change as well. Despite these limitations, we hope that our efforts will promote more focused thinking about sustainability and its measurement, as well as change people's priors about whether the criterion is being satisfied in the U.S. and China.

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[11] See Ehrlich and Goulder (2006) for a discussion of potential limitations in existing comprehensive wealth studies, including biases from omissions of certain environmental damages.

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Table 1

Natural Capital Stocks: Quantities, Prices and Values, 1995-2000

UNITED STATES

	Oil	Natural Gas	Copper	Lead	Phosphate	Forests	Land	**TOTAL Natural Capital**
Capital Stock in 1995	54.91	10,222.03	0.099	0.022	4.200	26.942		
Capital Stock in 2000	40.28	7,495.83	0.090	0.020	4.000	26.976		
Change in Stock 1995-2000	-14.63	-2,726	-0.009	-0.002	-0.200	0.034		
Average Price	..	..	2231	823	42			
Average Extraction Cost	..	..	1513	634	7			
Accounting Price	2.479	0.015	718	189	7	52		
Value of 1995 Stock	136.154	148.694	70.886	4.230	30.829	1,113.923	1,779.705	**3,284.421**
Value of change in Stock	-36.274	-39.656	-6.288	-0.449	-1.465	1.732		**-82.400**

CHINA

	Oil	Natural Gas	Copper	Lead	Phosphate	Forests	Land	**TOTAL Natural Capital**
Capital Stock in 1995	27.88	2,482.17	0.040	0.033	1.315	12.390		
Capital Stock in 2000	22.02	2,366.27	0.037	0.030	1.200	12.450		
Change in Stock 1995-2000	-5.87	-115.90	-0.003	-0.003	-0.115	0.060		
Average Price	..	..	2231	823	42			
Average Extraction Cost	..	..	1717	696	42			
Accounting Price	6.025	0.058	..	126	..	30		
Value of 1995 Stock	168.016	144.671	..	4.192	..	301.703	2,027.808	**2,646.391**
Value of change in Stock	-35.358	-6.755	..	-0.398	..	1.819		**-40.692**

Table 2
Comprehensive Investment and Its Components

UNITED STATES

	TOTAL Natural Capital	Human Capital	Reproducible Capital	Oil Net Capital Gains	Carbon Damages	**Sum: Comprehensive Investment**
Capital Stock in 1995		0.5419326	13443.5100			
Capital Stock in 2000		0.5844646	16002.9400			
Change in Stock 1995-2000		0.04253	2,559.430			
Accounting Price		139,092.484	1			
Value of 1995 Stock	**3,284.421**	75,378.750	13,443.510			**92,106.682**
Value of change in Stock	**-82.400**	5,915.888	2,559.430	-1,367.580	-150.203	**6,875.134**
Relative Contribution	-1.20%	86.05%	37.23%	-19.89%	-2.18%	
Percent Change						**7.46%**
Growth Rate						**1.45%**

CHINA

	TOTAL Natural Capital	Human Capital	Reproducible Capital	Oil Net Capital Gains	Carbon Damages	**Sum: Comprehensive Investment**
Capital Stock in 1995		1.6228843	4093.4500			
Capital Stock in 2000		1.7951992	6311.0100			
Change in Stock 1995-2000		0.172	2,217.560			
Accounting Price		6,997.466	1			
Value of 1995 Stock	**2,646.391**	11,356.077	4,093.450			**18,095.918**
Value of Change in Stock	**-40.692**	1,205.767	2,217.560	-305.850	-8.127	**3,068.658**
Relative Contribution	-1.33%	39.29%	72.26%	-9.97%	-0.26%	
Percent Change						**16.96%**
Growth Rate						**3.18%**

Table 3

Growth Rates of Per-Capita Comprehensive Wealth, Adjusted for Technological Change

	(1) Comprehensive Wealth Growth Rate	(2) Population Growth Rate	(3) Per Capita Comprehensive Wealth Growth Rate, Accounting for Population Growth [(1)+(2)]	(4) TFP Growth Rate	(5) Per Capita Comprehensive Wealth Growth Rate, Accounting for TFP growth [(3)+(4)]	(6) Per Capita GDP Growth Rate
US	1.45%	1.10%	0.35%	1.48%	1.83%	4.44%
CHINA	3.18%	0.84%	2.34%	2.71%	5.05%	7.38%

Appendix

1. General Data

Population

We extracted population from the World Development Indicators (http://devdata.worldbank.org).

TABLE A1. Population in US and China 1995-2000

	1995	1996	1997	1998	1999	2000
US	266,278,000	269,393,984	272,656,992	275,854,016	279,040,000	282,224,000
China	1,204,855,040	1,217,549,952	1,230,075,008	1,241,934,976	1,253,735,040	1,262,644,992

GDP

GDP data were obtained from the World Development Indicators. Data are in current US dollars.

TABLE A2. Gross Domestic Product, US and China, 1995-2000

	1995	1996	1997	1998	1999	2000
US	7,342,300,069,888	7,762,299,846,656	8,250,900,086,784	8,694,599,778,304	9,216,199,753,728	9,764,800,036,864
China	700,277,784,576	816,489,824,256	898,243,690,496	946,300,846,080	991,355,666,432	1,080,741,396,480

TFP

Total Factor Productivity data were obtained from Peter Klenow (unpublished data). These data were employed in Klenow (2006).

TABLE A3. TFP for US and China, 1995-2000

	1995	1996	1997	1998	1999	2000
US	620.99	628.15	639.57	647.97	656.91	668.26
China	187.59	190.92	193.71	198.22	200.98	214.38

2. Data on Natural Resources

Oil

The year-end 2004 proved reserves for the U.S. and China were obtained from the *BP Statistical Review of World Energy* (2005). We also obtained oil production (extraction) for both countries in each year from 1995 to 2004 from this publication. The stock of oil in years 1995 – 2003 are given by adding the production from the previous year to the stock from the previous year:

$$Stock_{t-1} = Stock_t + \Pr oduction_t$$

The calculated stock values, along with production and consumption for each country, are given in Table A4.

Table A4: Oil Stock, Production, and Consumption in billions of barrels 1995 - 2004

US	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Stock	54.91	51.88	48.86	45.94	43.11	40.28	37.48	34.70	32.00	29.35
Production	3.04	3.04	3.02	2.92	2.82	2.83	2.80	2.78	2.70	2.65
Consumption	6.47	6.70	6.80	6.90	7.12	7.21	7.17	7.21	7.31	7.51

CHINA	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Stock	27.88	26.72	25.55	24.38	23.21	22.02	20.81	19.59	18.35	17.07
Production	1.09	1.16	1.17	1.17	1.17	1.19	1.21	1.22	1.24	1.28
Consumption	1.24	1.34	1.44	1.48	1.61	1.82	1.84	1.96	2.11	2.45

Source: BP Statistical Review of World Energy and authors' calculations

The wealth of a country includes the value of the stock of oil net of extraction costs. If the price of a barrel of oil is $30, but it costs $20 for each barrel that is extracted, the value of a barrel of oil to the country is $10. This type of calculation requires some simplifying assumptions. First oil is not a homogenous good. There are, in fact, many different grades of oil with corresponding prices. Second, over the time period in this study, 1995-2000, the price of any particular grade of oil varies significantly. We average both over oil grades and over time to calculate an average price of oil for the 1995-2000 period. To calculate this price, we use the real average of spot prices over 1995 to 2000 for four types of crude: Dubai, Brent, Nigerian Forcados, and West Texas Intermediate. We adjust the prices by the CPI-U to account for inflation before averaging over time. The prices are reported in Table A5. Using this method, the average world price of oil for 1995-2000 is $20.21 per barrel.

Table A5: Spot Prices for Crude Oil and Average World Price for 1995-2000

	1995	1996	1997	1998	1999	2000
Dubai	16.10	18.52	18.23	12.21	17.25	26.20
Brent	17.02	20.67	19.09	12.72	17.97	28.50
Nigerian Forcados	17.26	21.16	19.33	12.62	18.00	28.42
West Texas	18.42	22.16	20.61	14.39	19.31	30.37
Average Price	**17.20**	**20.63**	**19.32**	**12.99**	**18.13**	**28.37**
Average Real Price	**18.67**	**21.98**	**20.24**	**13.46**	**18.53**	**28.37**

Source: BP Statistical Review of World Energy (2005)

The estimated cost of extraction is obtained from the World Bank (2005). The World Bank uses several studies of the costs of oil extraction and combines them into a large database. While there are several estimates of the costs of oil extraction in the U.S., there are none for China. Because there is no estimate, we assume that the cost of oil extraction in China is 80% of the cost in the U.S. Oil production in China is actually quite similar to U.S. oil production. China has a large number of off-shore facilities and even though labor costs are considerably less, the oil industry is particularly capital intensive. The 80% assumption is based on conversations with energy experts, but even so, it is a fairly arbitrary assumption. Our estimate of the cost of oil extraction is $17.73 per barrel in the U.S. and $14.18 per barrel in China. The calculated rent from oil is $2.48 in the U.S. and $6.03 in China.

Natural Gas

The end of year 2004 proved reserves for the U.S. and China were obtained from the *BP Statistical Review of World Energy* (2005). We also obtained natural gas production (extraction) for both countries in each year from 1995 to 2004 from this publication. The stock of natural gas in years 1995 – 2003 are given by adding the production from the previous year to the stock from the previous year:

$$Stock_{t-1} = Stock_t + \Pr oduction_t$$

The calculated stock values, along with production and consumption for each country, are given in Table A6.

Table A6: Natural Gas Stock, Production, and Consumption in billion cubic meters 1995 - 2004

US	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Stock	10218.8	9677.1	9134.0	8584.8	8043.2	7492.6	6926.8	6382.5	5832.9	5290.0
Production	534.3	541.7	543.1	549.2	541.6	550.60	565.8	544.3	549.6	542.9
Consumption	638.0	649.6	653.2	642.2	644.3	669.70	641.4	661.6	645.3	646.7

CHINA	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Stock	2483.3	2463.4	2441.2	2418.9	2394.6	2367.4	2337.1	2305.2	2270.8	2230.0
Production	17.6	19.9	22.2	22.3	24.3	27.2	30.3	31.9	34.4	40.8
Consumption	17.7	17.7	19.3	19.3	21.4	24.5	27.8	29.6	32.8	39.0

Source: BP Statistical Review of World Energy and authors' calculations

The wealth of a country includes the value of the stock of natural gas net of extraction costs. We average both over natural gas source and over time to calculate an average price of natural gas for the 1995-2000 period. To calculate this price, we use the real average of spot prices over 1995 to 2000 for four natural gas sources:. We adjust the prices by the CPI-U to account for inflation before averaging over time. The prices are reported in Table A7. Using this method, the average world price of natural gas for 1995-2000 is $102.42 per thousand cubic meters.

Table A7: Spot Prices for Natural Gas in thousand cubic meters and Average World Price, 1995-2000

	1995	1996	1997	1998	1999	2000
U.S.	61.53	100.49	92.12	75.73	82.65	154.01
U.K.	-	67.36	73.91	69.91	59.71	97.58
Japan	125.98	133.26	142.36	111.05	114.32	171.85
European Union	86.29	88.47	96.48	82.28	65.54	118.33
Average Price	**91.27**	**97.39**	**101.22**	**84.74**	**80.56**	**135.44**
Average Real Price	**99.09**	**103.77**	**106.08**	**87.84**	**82.31**	**135.44**

Source: BP Statistical Review of World Energy (2005)

The estimated cost of natural gas production is obtained from the World Bank (2005). The World Bank uses several studies of the costs of oil extraction and combines them into a large database. While there are several estimates of the costs of natural gas extraction in the U.S., again, there are none for China. Because there is no estimate, we assume that the cost of natural gas extraction in China is equal to the average cost of natural gas extraction in the world. Our estimate of the cost of natural gas production is $87.88 per thousand cubic meters in the U.S. and $44.14 per thousand cubic meters in China. The calculated rent from natural gas is $14.55 in the U.S. and $58.28 in China.

Metals and Minerals

To get stock, production, cost, and price data, we used a number of sources and applied estimation techniques across all metals and minerals. In general, we used the same data and methods described in the World Bank's Manual for Calculating Net Adjusted Savings (Bolt, Matete et al. 2002) and Where is the Wealth of Nations (World Bank 2005). We briefly describe these below.

We set the stock, or the reserves, of all metals and minerals in 2000 equal to the reserve base, i.e. the proven reserve plus the probable reserve, as reported in the US Bureau of Mines' Mineral Commodity Summaries. Proven reserves are profitably exploitable under current economic conditions, while probable reserves are less certain, but also thought to be exploitable under current economic conditions at some point in the future.

Production numbers for most minerals are fairly complete in the World Bank dataset. These are based on USGS numbers published in their Mineral Commodities Summary and/or Minerals Year Book, extrapolated linearly to fill in gaps of missing years.

Given the estimated stock of an exhaustible resource at the end of year *t*, the stock at the end of year *t*-1 is given by

$$Stock_{t-1} = Stock_t + \Pr oduction_t$$

where the production in year *t* measures the amount of the resource extracted between year *t*-1 and year *t*.

Extraction cost data are proprietary and therefore very difficult to obtain. We used the World Bank dataset, which compiled data on a wide array of sources and expert opinion.

World market prices came from UNCTAD's Monthly Commodity Price Bulletin.

If, for all years in 1995-2000, price was greater than cost, we averaged the difference between annual real price and annual real extraction cost, adjusted to year 2000 dollars, to obtain our measure of the average unit rent for the period 1995-2000.

Copper

TABLE A8a. US Copper stock, production, and extraction costs

US							
		1995	**1996**	**1997**	**1998**	**1999**	**2000**
Stock	metric tons	98,760,000	96,840,000	94,900,000	93,040,000	91,440,000	90,000,000
Production	metric tons	1,850,000	1,920,000	1,940,000	1,860,000	1,600,000	1,440,000
Extraction Costs	*US$/metric ton*	*1,394*	*1,420*	*1,444*	*1,460*	*1,481*	*1,513*
Extraction costs	*Y2000 $/metric ton*	*1,513*	*1,513*	*1,513*	*1,513*	*1,513*	*1,513*
						average	***1,513***

TABLE A8b. China Copper stock, production, and extraction costs

CHINA		**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Stock	metric tons	39,531,100	39,092,000	38,596,000	38,110,000	37,590,000	37,000,000
Production	metric tons	445,200	439,100	496,000	486,000	520,000	590,000
Extraction Costs	*US$/metric ton*	*1,581*	*1,611*	*1,638*	*1,656*	*1,680*	*1,717*
Extraction costs	*Y2000 $/metric ton*	*1,717*	*1,717*	*1,717*	*1,717*	*1,717*	*1,717*
						average	***1,717***

TABLE A8c. World market price for Copper, 1995-2000

		1995	**1996**	**1997**	**1998**	**1999**	**2000**
Average Price	US$/metric ton	2981	2355	2294	1671	1607	1862
Price Y2000	Y2000 $/metric ton	3236	2509	2404	1732	1642	1862
						average	**2231**

TABLE A8d. Average unit rent for Copper, 1995-2000

	1995	**1996**	**1997**	**1998**	**1999**	**2000**	average
US	1,723	996	891	219	129	349	718
CHINA	1,519	793	687	15	0	145	..

Lead

TABLE A9a. US Lead stock, production, and extraction costs

US		**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Stock	metric tons	22,373,000	21,937,000	21,478,000	20,985,000	20,465,000	20,000,000
Production	metric tons	394,000	436,000	459,000	493,000	520,000	465,000
Extraction Costs	*US$/metric ton*	*584*	*595*	*605*	*611*	*620*	*634*
Extraction costs	*Y2000 $/metric ton*	*634*	*634*	*634*	*634*	*634*	*634*
						average	***634***

TABLE A9b. China Lead stock, production, and extraction costs

CHINA		**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Stock	metric tons	33,144,000	32,501,000	31,789,000	31,209,000	30,660,000	30,000,000
Production	metric tons	520,000	643,000	712,000	580,000	549,000	660,000
Extraction Costs	*US$/metric ton*	*641*	*654*	*665*	*672*	*682*	*696*
Extraction costs	*Y2000 $/metric ton*	*696*	*696*	*696*	*696*	*696*	*696*
						average	***696***

TABLE A9c. World market price for Lead, 1995-2000

		1995	**1996**	**1997**	**1998**	**1999**	**2000**
Average Price	US$/metric ton	778	922	825	763	733	707
Price Y2000	Y2000 $/metric ton	844	983	864	791	749	707
						average	**823**

TABLE A9d. Average unit rent for Lead, 1995-2000

	1995	**1996**	**1997**	**1998**	**1999**	**2000**	average
US	210	349	231	157	115	73	189
CHINA	148	286	168	94	52	10	126

Phosphate

TABLE A10a. US Phosphate stock, production, and extraction costs

US		**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Stock	metric tons	4,199,600,000	4,154,200,000	4,108,300,000	4,072,200,000	4,036,100,000	4,000,000,000
Production	metric tons	43,500,000	45,400,000	45,900,000	36,100,000	36,100,000	36,100,000
Extraction Costs	*US$/metric ton*	*32*	*33*	*33*	*34*	*34*	*35*
Extraction costs	*Y2000 $/metric ton*	*35*	*35*	*35*	*35*	*35*	*35*
						average	***35***

TABLE A10b. China Phosphate stock, production, and extraction costs

CHINA		**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Stock	metric tons	1,314,500,000	1,293,500,000	1,269,000,000	1,246,000,000	1,223,000,000	1,200,000,000
Production	metric tons	19,300,000	21,000,000	24,500,000	23,000,000	23,000,000	23,000,000
Extraction Costs	*US$/metric ton*	*46*	*47*	*48*	*48*	*49*	*50*
Extraction costs	*Y2000 $/metric ton*	*50*	*50*	*50*	*50*	*50*	*50*
						average	***50***

TABLE A10c. World market price for Phosphate, 1995-2000

		1995	**1996**	**1997**	**1998**	**1999**	**2000**
Average Price	US$/metric ton	35	38	41	42	44	44
Price Y2000	Y2000 $/metric ton	38	40	43	44	45	44
						average	***42***

TABLE A10d. Average unit rent for Phosphate, 1995-2000

	1995	**1996**	**1997**	**1998**	**1999**	**2000**	average
US	3	6	8	9	10	9	7
CHINA	0	0	0	0	0	0	..

Forests

FAO calculates each country’s total forest stock from estimates of average stock per hectare for each region applied to the total forested area in each nation. FRA 2005 data confirm that the productive functions of global forest resources have not changed significantly in the past 15 years; the density of wood per hectare and total growing stock are relatively steady at the global level.

We obtained total cubic meters of commercially available forests from the Food and Agriculture Organization (FAO) Forestry Resources Assessment (FRA) (FAO 2005). These data include volumes of growing stock of forests and other wooded resources in 1990, 2000, and 2005, and designate the amount of total stock that is commercially available. FAO calculates each country’s total forest stock from estimates of average stock per hectare for each region applied to the total forested area in each nation.

We calculated a linear growth rate between 1990 and 2000 to get stock data for individual years. The difference in stock from one year to the next is assumed to be “produced” (if negative) or “afforested” (if positive). For both the US and China, stock increased over 1995-2000. For 2000, the production was set equal to production in 1999 (as no stock was calculated for 2001).

$$\text{Production}_t = \text{Stock}_t - \text{Stock}_{t+1}$$

TABLE A11a. US Commercially Available Forest Stock, 1995-2000

US		1995	1996	1997	1998	1999	2000
Stock	billion cubic meters	26.9425	26.9492	26.9559	26.9626	26.9693	26.9760
Production	billion cubic meters	0.0067	0.0067	0.0067	0.0067	0.0067	0.0067

TABLE A11b. China Commercially Available Forest Stock, 1995-2000

China		1995	1996	1997	1998	1999	2000
Stock	billion cubic meters	12.3902	12.4022	12.4141	12.4261	12.4380	12.4500
Production	billion cubic meters	0.0120	0.0120	0.0120	0.0120	0.0120	0.1395

Rental price for forests equals the weighted average market price of the types of wood minus the extraction and afforestation costs. World market prices are a weighted average for fuel and roundwood, according to the formula:

$$P_r = Q_f * (P_f) + (1 - Q_f) * (P_e)$$

where,
P_r = Weighted average price of roundwood
P_f = Price of fuelwood
P_e = Export price of industrial roundwood (which does not reflect fuelwood)
Q_f = Fuelwood quotient, i.e. percentage of total roundwood production that is fuelwood

TABLE A11c. Weighted Average Roundwood Prices, US and China, 1995-2000

		1995	1996	1997	1998	1999	2000
USA	current US$/cum	147	149	135	94	106	109
	Y2000 $/cum	*160*	*159*	*141*	*98*	*109*	*109*
						average	***129***
CHINA	current US$/cum	65	67	60	53	50	55
	Y2000 $/cum	*71*	*71*	*62*	*55*	*51*	*55*
						average	***61***

With these inputs, we can calculate the average unit rent for forests.

TABLE A11h. Average Unit Rent for Forests, 1995-2000, Y2000 dollars

	1995	**1996**	**1997**	**1998**	**1999**	**2000**	average
US	64	63	56	39	43	44	52
CHINA	35	35	31	27	25	28	30

Land

Where is the Wealth of Nations (2005) provides the following estimates of land values.

TABLE A11. Components of Land Value, $ Per Capita, 2000

	Non-timber forest resources	Protected Areas	Cropland	Pasture land	Total Land Value
US	238	1,651	2,752	1,665	6,306
China	29	27	1,404	146	1,606

Carbon Damages

TABLE A11. Carbon Emissions, 000 tons Carbon

	1995	1996	1997	1998	1999	2000	Total (96-00)
US	1,416,796	1,438,965	1,485,985	1,499,690	1,501,796	1,527,684	7,454,120
CHINA	872,086	911,655	898,166	850,076	770,461	761,032	4,191,390
GLOBAL	6,053,892	6,053,892	6,053,892	6,053,892	6,053,892	6,053,892	30,269,462

Oil Capital Gains

In the oil section, we try to measure the change in wealth due to changes in the quantity of oil given a fixed price. Here, we try to measure the change in wealth due to changes in price given a fixed quantity. A country with a stock of oil chooses how much to extract each year, subject to a capacity constraint. As the world stock of oil decreases, the price increases driving up the scarcity rent.

We assume that the scarcity rent increases by 5% per year. Oil that was not extracted during the 1995-2000 period then would have increased in value by 27.6%. For each country (or region where the data does not allow desegregation) we calculate the value of the stock of oil remaining in 2000 and then multiply this by the assumed increase in prices to find the capital gains.

Capital gains to countries with oil are paid for by countries that consume oil in terms of higher prices. The world total oil capital gains are distributed as a loss to each country in proportion to the fraction of world total oil consumption. Since the U.S. accounted for 25.7% of world oil consumption, it is assigned a loss equal to 25.7% of world total oil capital gains due to the increasing price of oil.

We obtain the level of oil reserves in 2004 from the *BP Statistical Review of World Energy* (2005) and then calculate the level of oil reserves in 2000 in the same method as described in the oil section above. The production data used to make these calculations and the consumption data used in calculating the percent of world consumption is also obtained from the *BP Statistical Review of World Energy* (2005). The extraction cost data is from the World Bank (2005). Extraction cost data is missing for some countries.

Table A12: Oil Reserves, Consumption, and Capital Gains 1995-2000

Country or Region	**Extraction Cost** 95-00 Ave	**Rent per Barrel** 95-00 Ave	**2000 Reserves** Billions Barrels	**Gross Capital Gain** $ Billions	**Consumption** % of World (95-00)	**Net Capital Gain** $ Billions
US	17.7	2.51	40.28	$27.93	25.73%	-$1,367.38
Canada	24.4	0	20.94	$0.00	2.63%	-$142.50
Mexico	4.3	15.91	20.06	$88.16	2.43%	-$43.37
Argentina	15.3	4.91	3.82	$5.18	0.56%	-$25.04
Brazil	17.7	2.51	13.36	$9.26	2.37%	-$119.05
Colombia	21.7	0	2.38	$0.00	0.33%	-$17.72
Ecuador	4.2	16.01	5.69	$25.18	0.18%	$15.62
Peru	10.7	9.51	1.07	$2.80	0.20%	-$8.18
Trinidad & Tobago	8.1	12.11	1.21	$4.04	0.01%	$3.50
Venezuela	4.3	15.91	81.52	$358.32	0.67%	$322.04
Other S. & C. America	18	2.21	1.60	$0.98	1.55%	-$82.97
Azerbaijan	10	10.21	7.44	$20.99	0.16%	$12.47
Denmark	15	5.21	1.86	$2.67	0.28%	-$12.73
Italy	15	5.21	0.88	$1.27	2.60%	-$139.96
Kazakhstan	10	10.21	41.14	$116.04	0.25%	$102.66
Norway	15	5.21	14.37	$20.69	0.28%	$5.24
Romania	10	10.21	0.65	$1.83	0.31%	-$14.85
Russia	8.1	12.11	83.88	$280.63	3.42%	$95.04
Turkmenistan	10	10.21	0.81	$2.29	0.10%	-$2.96
United Kingdom	17.4	2.81	7.77	$6.03	2.31%	-$119.47
Uzbekistan	10	10.21	0.83	$2.34	0.18%	-$7.49
Other Eruope & Eurasia	15	5.21	2.60	$3.74	15.53%	-$838.27
Iran	0.8	19.41	137.88	$739.40	1.73%	$645.43
Iraq	0.8	19.41	117.77	$631.57	0.38%	$610.96
Kuwait	1.6	18.61	102.07	$524.79	0.26%	$510.95
Oman	4.3	15.91	6.81	$29.92	0.07%	$26.12
Qatar	4	16.21	16.47	$73.76	0.07%	$69.86
Saudi Arabia	0.8	19.41	276.63	$1,483.45	1.95%	$1,377.64
Syria	4	16.21	3.95	$17.71	1.00%	-$36.53
United Arab Emirates	6	14.21	101.28	$397.61	0.40%	$375.97
Yeman	6	14.21	3.50	$13.73	0.40%	-$7.97
Other Middle East			0.00	$0.00	0.50%	-$27.12

(Continued)

Table A12 (continued): Oil Reserves, Consumption, and Capital Gains 1995-2000

Country or Region	**Extraction Cost** 95-00 Ave	**Rent per Barrel** 95-00 Ave	**2000 Reserves** Billions Barrels	**Gross Capital Gain** $ Billions	**Consumption** % of World (95-00)	**Net Capital Gain** $ Billions
Algeria	15	5.21	14.30	$20.59	0.27%	$5.82
Angola	15	5.21	10.06	$14.47	0.05%	$11.76
Chad	15	5.21	0.97	$1.39	0.01%	$0.85
Rep. of Congo	15	5.21	2.14	$3.09	0.01%	$2.54
Egypt	11.9	8.31	4.62	$10.61	0.72%	-$28.48
Equatorial Guinea	15	5.21	1.64	$2.36	0.01%	$1.82
Gabon	13	7.21	2.67	$5.31	0.02%	$4.23
Libya	4.3	15.91	41.22	$181.21	0.29%	$165.48
Nigeria	4.3	15.91	38.51	$169.28	0.37%	$149.22
Sudan	15	5.21	6.67	$9.60	0.08%	$5.26
Tunisia	15	5.21	0.74	$1.07	0.11%	-$4.90
Other Africa	15	5.21	0.80	$1.15	0.89%	-$47.12
Australia	15	5.21	4.98	$7.17	1.11%	-$52.93
Brunei	15	5.21	1.35	$1.94	0.02%	$0.86
China	14.16	6.05	22.02	$36.81	6.32%	-$305.80
India	15	5.21	6.70	$9.65	2.82%	-$143.03
Indonesia	7.1	13.11	6.50	$23.53	1.35%	-$49.57
Malaysia	4.3	15.91	5.51	$24.23	0.59%	-$7.80
Thailand	15	5.21	0.79	$1.13	1.03%	-$54.50
Vietnam	15	5.21	3.49	$5.03	0.26%	-$9.07
Other Asia Pacific	15	5.21	0.90	$1.30	14.86%	-$804.60
			WORLD TOTAL	**$5,423.23**	**100.00%**	**$0.00**

Source: PB Review (2005) and estimates of the country-specific average extraction costs (if unavailable a value of 15 is used for the calculations).

3. Human Capital

We use an estimate of the average educational attainment reported in Klenow and Rodríguez-Clare (2005) to construct a measure the stock of human capital. The stock of human capital for an individual, *h*, is given by

$$h = e^{0.085(\text{educational attainment})}$$

where 0.085 is the assumed rate of return on human capital. To find the aggregate stock of human capital, *H*, we simply multiply *h* by the population of the county. Rather than use the total population, we exclude children under the age of 11 in China and under the age of 17 in the United States because they have not yet built up their stock of human capital.

The average educational attainment increased during the 1995-2000 period. China experienced a growth of 4%, while the U.S. had slightly more than 1% growth during the period (see table X). The age 10 or more population in each country also increases over the 1995-2000 time period. China experienced 8.6% growth and the U.S. experienced 6.7% growth (see table X). Note that our measure of the aggregate human capital stock increases both as the average educational attainment increases and as the population of age 10 or more increases.

Table A13: Education, Population, and Human Capital Stock 1995-2000

	CHINA				US			
Year	Average Education Attainment	Average Human Capital (h)	Population Age 11 + (thousands)	Human Capital Stock (H)	Average Education Attainmen	Average Human Capital (h)	Population Age 17 + (thousands)	Human Capital Stock (H)
1995	6.111	1.68108	965,382	1,622,884,318	11.892	2.74785	197,221	541,932,590
1996	6.160	1.68809	979,216	1,653,004,350	11.923	2.75510	199,569	549,831,670
1997	6.209	1.69514	997,315	1,690,588,728	11.955	2.76261	202,139	558,431,592
1998	6.257	1.70207	1,013,298	1,724,703,967	11.986	2.76990	204,683	566,951,779
1999	6.306	1.70917	1,029,251	1,759,164,853	12.018	2.77744	207,250	575,623,498
2000	6.355	1.71631	1,045,964	1,795,199,173	12.049	2.78477	209,879	584,464,633

Populaion: U.S. Census Bureau International Database (http://www.census.gov/ipc/www/idbnew.html)

As table A13 shows, the aggregate stock of human capital increased almost 11% in China and slightly more than 8% in the U.S.

We now need to find the price of a unit of human capital in order to place a value on the stock. The methodology here is to first calculate the rental price for an employed unit of human capital and then to find the average number of working years remaining for the population age 10 or more. The value of a unit of human capital is the discounted sum of the rental price, *r*, for the average number of working years remaining.

$$P_{K_H} = \int_{t=0}^{years} r \; e^{-0.085t} dt$$

The rental price of a unit of human capital is simply the country's total wage bill divided by the employed number of human capital units (not the whole human capital stock). The total wage bill in the US is easily obtained from the national income accounts. China's national income accounting method does not report total wages or compensation, so this is calculated from information provided by the *China Statistical Yearbook*. Employment in both countries is obtained from Klenow and Rodriguez-Clare (2005). We use the average price for the time period. The average rental price per year for a unit of human capital is \$528.11 in China and \$12,807.98 in the U.S.

Table A14: Total Wage Bill for China and the U.S. 1995-2000

Year	CHINA Avg. Wage ($US)	CHINA Employment (thousands)	CHINA Wage Bill ($billions)	U.S. Wage Bill ($billions)
1995	684	727,832	497.8	4,177
1996	772	735,241	567.6	4,387
1997	805	742,369	597.6	4,665
1998	930	749,197	696.8	5,020
1999	1,038	756,055	784.8	5,352
2000	1,166	763,855	886.1	5,783

Average Wage (nominal) Source: China Statistical Yearbook 2002: Table 5-20
http://www.stats.gov.cn/english/statisticaldata/yearlydata/YB2002e/ml/indexE.htm
Employment Source: Klenow, P. and Rodriguez-Clare, A. Handbook Chapter (Data Appendix)
U.S. Wage Bill = Total compensation from national income account, BEA

Table A15: Rental Price of Human Capital in China and the U.S. 1995-2000

	CHINA			U.S.		
Year	Wage Bill ($billions)	Human Capital Stock (H)	Rental price of one unit of human capital	Wage Bill ($billions)	Human Capital Stock (H)	Rental price of one unit of human capital
1995	497.84	1,223,541,238	406.88	4177	366,310,386	11,402.90
1996	567.61	1,241,156,279	457.32	4387	372,957,055	11,762.75
1997	597.61	1,258,419,442	474.89	4665	379,093,145	12,305.68
1998	696.75	1,275,185,340	546.39	5020	384,372,859	13,060.24
1999	784.79	1,292,229,879	607.31	5352	390,452,142	13,707.19
2000	886.07	1,311,009,179	675.87	5783	395,848,675	14,609.12

CHINA: Average rental price of one unit of human capital = $**528.11**
US: Average rental price of one unit of human capital = **$12,807.98**

Table A16: Population, Mortality, and Years of Work Remaining for Males in China

	Population	Active Percentage	Active Population	Mortality Probability	Avg. Work Remaining
0-4	51091760	0	0	0.03759	43.0
5-9	54254180	0	0	0.00314	44.7
10-14	62010528	0	0	0.00269	44.8
15-19	52665280	63.86	33632048	0.00578	41.7
20-24	50961980	92.8	47292717	0.00718	37.3
25-29	62313660	98.61	61447500	0.00674	32.7
30-34	64799528	99.02	64164493	0.00732	28.0
35-39	53963232	99.15	53504545	0.00946	23.2
40-44	43936400	98.95	43475068	0.01406	18.5
45-49	44348360	97.94	43434784	0.02256	13.8
50-54	32585930	93.55	30484138	0.0368	9.5
55-59	24418930	83.88	20482598	0.05939	5.7
60-64	21478200	63.75	13692353	0.09408	2.8
65-69	17625390	33.59	5920369	0.14642	1.4
70-74	11991350	33.59	4027894	0.22671	0.0
75-79	6863370	0	0	0.34238	0.0
80-84	3015910	0	0	0.49999	0.0
85-89	903120	0	0	0.67919	0.0
90-94	163110	0	0	0.79408	0.0
95-99	16994	0	0	0.85642	0.0
100+	1091	0	0	1	0.0

Sources: World Health Organization Life Tables 2000, US Census Bureau IDB demographic data 1990

Table A17: Population, Mortality, and Years of Work Remaining for Females in China

	Population	Active Percentage	Active Population	Mortality Probability	Avg. Work Remaining
0-4	45892300	0	0	0.04389	35.1
5-9	48638800	0	0	0.00264	36.7
10-14	56168520	0	0	0.0018	36.8
15-19	48594528	71.4	34696493	0.00238	33.3
20-24	47770000	91.68	43795536	0.0032	28.8
25-29	59211928	91.56	54214441	0.0041	24.3
30-34	62217712	91.3	56804771	0.00529	19.9
35-39	51377952	91.28	46897795	0.00743	15.4
40-44	40608800	88.37	35885997	0.01049	11.1
45-49	41938880	81.12	34020819	0.01603	7.2
50-54	30147800	62	18691636	0.02465	4.2
55-59	22592370	45.07	10182381	0.03787	2.0
60-64	20259450	27.44	5559193	0.06183	0.8
65-69	17690780	8.44	1493102	0.10341	0.4
70-74	13294740	8.44	1122076	0.17766	0.0
75-79	9051270	0	0	0.29618	0.0
80-84	4898760	0	0	0.45765	0.0
85-89	1955500	0	0	0.64713	0.0
90-94	591650	0	0	0.77727	0.0
95-99	112775	0	0	0.84928	0.0
100+	11490	0	0	1	0.0

Sources: World Health Organization Life Tables 2000, US Census Bureau IDB demographic data 1990

Table A18: Population, Mortality, and Years of Work Remaining for Males in the U.S.

	Population	Active Percentage	Active Population	Mortality Probability	Avg. Work Remaining
0-4	10265130	0	0	0.00936	40.3
5-9	10716110	0	0	0.00093	40.6
10-14	10508530	0	0	0.00123	40.7
15-19	10125050	53.2	5386527	0.00474	38.1
20-24	9445860	82.5	7792835	0.00706	34.1
25-29	9523560	92.94	8851197	0.00706	29.7
30-34	10369200	93.44	9688980	0.00784	25.3
35-39	11693900	92.74	10844923	0.01043	20.8
40-44	11610640	91.96	10677145	0.01499	16.4
45-49	10217120	90.76	9273058	0.02274	12.2
50-54	8788100	86.9	7636859	0.03233	8.1
55-59	6703200	77.87	5219782	0.04915	4.5
60-64	5236380	54.28	2842307	0.07541	2.0
65-69	4431380	27.53	1219959	0.11333	0.8
70-74	3927820	17.3	679513	0.16984	0.0
75-79	3059800	7.3	223365	0.24554	0.0
80-84	1835290	0	0	0.36599	0.0
85-89	836240	0	0	0.52072	0.0
90-94	283400	0	0	0.65771	0.0
95-99	68020	0	0	0.76489	0.0
100+	10130	0	0	1	0.0

Sources: World Health Organization Life Tables 2000, US Census Bureau IDB demographic data 1990

Table A19: Population, Mortality, and Years of Work Remaining for Females in the U.S.

	Population	Active Percentage	Active Population	Mortality Probability	Avg. Work Remaining
0-4	9777090	0	0	0.00766	33.9
5-9	10215890	0	0	0.00072	34.1
10-14	10024470	0	0	0.00082	34.2
15-19	9661220	51.3	4956206	0.00199	31.6
20-24	9111120	71.3	6496229	0.0024	28.1
25-29	9335700	75.82	7078328	0.00282	24.4
30-34	10205140	74.67	7620178	0.00378	20.7
35-39	11447350	76.55	8762946	0.00573	17.0
40-44	11454940	78.62	9005874	0.00859	13.2
45-49	10275640	78.03	8018082	0.01263	9.4
50-54	8995740	71.85	6463439	0.0191	5.9
55-59	7022870	59.79	4198974	0.03013	3.0
60-64	5668660	38.16	2163161	0.04802	1.2
65-69	5059830	17.17	868773	0.07376	0.4
70-74	4883870	8.77	428315	0.11263	0.0
75-79	4289810	3.1	132984	0.17444	0.0
80-84	3064520	0	0	0.27776	0.0
85-89	1836230	0	0	0.42268	0.0
90-94	876230	0	0	0.57447	0.0
95-99	302880	0	0	0.71	0.0
100+	65300	0	0	1	0.0

Sources: World Health Organization Life Tables 2000, US Census Bureau IDB demographic data 1990

4. Reproducible Capital

Table A21 shows the measure of the stock of reproducible capital in the U.S. and China that we obtained from Klenow and Rodriguez-Clare (2005).

Table A20: Reproducible Capital

	US Reproducible Capital	China Reproducible Capital
1995 Stock	13,850.63	4,196.03
2000 Stock	17,655.75	6,356.76

(billions of US dollars)

This is a measure of the reproducible capital located in the country. However, due to international investment, some of the stock of reproducible capital in a country is owned by investors outside of that country. In recent years, the U.S. has experienced a large trade deficit while China has experienced a trade surplus (see table X). This implies that other countries have a claim on a large stock of the reproducible capital in the U.S., while China is in the opposite position. That portion of the stock of reproducible capital that is not owned by the country in which it is located cannot be counted as part of its wealth. It is the stock of reproducible capital owned by a country regardless of its physical location that is a component of wealth.

In the U.S., net holdings of international assets are reported by the BEA. In developing countries, although capital flows are closely monitored, little work has been done on measuring the accumulated stocks of foreign assets and liabilities. We obtain estimates from a recent paper by Philip Lanea and Gian Maria Milesi-Ferretti (2006) that constructs net holdings of international assets from balance of payments and other IMF data.

Table A21: Current Account figures for U.S. and China 1995 - 2000

U.S. Current Account
(billions of US dollars)

Year	Total	Goods	Services	Income	Transfers
1995	-113.7	-174.2	77.8	20.9	-38.2
1996	-124.9	-191.0	86.9	22.3	-43.1
1997	-140.9	-198.1	89.8	12.6	-45.2
1998	-214.1	-246.7	81.7	4.3	-53.3
1999	-300.1	-346.0	82.6	13.9	-50.6
2000	-416.0	-452.4	74.1	21.1	-58.8

China Current Account
(billions of US dollars)

Year	Total	Goods	Services	Income	Transfers
1995	1.6	18.1	-6.1	-11.8	1.4
1996	7.2	19.5	-2.0	-12.4	2.1
1997	37.0	46.2	-3.4	-11.0	5.1
1998	31.5	46.6	-2.8	-16.6	4.3
1999	21.1	36.0	-5.3	-14.5	4.9
2000	20.5	34.5	-5.6	-14.7	6.3

sources: BEA (http://www.bea.gov/bea/di/home/bop.htm)
National Bureau of Statistics of China http://www.stats.gov.cn/english/
IMF 2002 Balance of Payments Statistics Yearbook part 1

Table A22: Net Holdings of International Assets 1995-2000

U.S. Net Holdings of International Assets billion US Dollars (cost valuation)				**China** Net Holdings of International Assets billion US Dollars	
Year	U.S. cost valuation	U.S. market valuation	Net External Position	Year	Net External Position
1995	-458.46	-305.84	-407.12	1995	-102.58
1996	-495.06	-360.02	-456.73	1996	-122.88
1997	-820.68	-822.73	-898.66	1997	-106.77
1998	-895.36	-1,070.77	-1,146.06	1998	-88.08
1999	-766.24	-1,037.44	-1,113.36	1999	-83.44
2000	-1,381.20	-1,581.01	-1,652.81	2000	-45.75

source: BEA http://www.bea.gov/bea/di/home/iip.htm
source: Lanea and Milesi-Ferretti (2006)
(http://www.tcd.ie/iiis/pages/people/planedata.php)

Table A23: Reproducible Capital Adjusted for International Holdings

	US Reproducible Capital	China Reproducible Capital
1995 Stock	13,443.51	4,093.45
2000 Stock	16,002.94	6,311.01

(billions of US dollars)