Tracing sustainability in the long run. Genuine Savings estimations 1850 - 2018[*]

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Abstract

This article presents a long-run view of sustainable development. We have introduced a new database on Genuine Savings (GS), an indicator propagated by the World Bank and widely used in contemporary economic research. GS derives from the theoretical work on wealth accounting, and addresses shortcomings in conventional metrics of economic development by incorporating broader measures of saving and investment, including human capital (education), and natural resource depletion. Its value as an indicator is determined the possibility to predict future standard of living on basis of genuine investments of the past. This article provides consistent historical estimates of GS since 1850 for 25 countries to enhance, complement and contextualise the work of the World Bank.

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JEL Codes: Q01, Q32, Q56, N50, N10

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1 Introduction

> *To maintain and augment the stock which may be reserved for immediate consumption, is the sole end and purpose both of the fixed and circulating capitals. It is this stock which feeds, cloaths, and lodges the people. Their riches or poverty depends upon the abundant or sparing supplies which those two capitals can afford to the stock reserved for immediate consumption.* (Smith, 1776, Book II, chapter I)
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> *The whole of history of man shows that his wants expand with the growth of his wealth and knowledge* (Marshall, 1920, Book IV, chapter VII, section 2)

This article introduces a new historic database of global Genuine Savings (GS) [1], a widely used economic indicator of sustainable development. The database is the first attempt to collect and collate existing estimates by several scholars to create a consistent database with a wide range of geographic coverage. It builds on work by researchers that has been primarily been published in environmental economics field journals (Rubio, 2004; Lindmark and Acar, 2013; Greasley et al., 2014; Hanley et al., 2015; Greasley et al., 2017). This work is complementary to existing collaborative research programmes in economic history, namely the Maddison Project (Bolt and van Zanden, 2014), by providing sustainability contexualisation to historic income growth. It also relates with recent work on historic measures of well-being (Prados de La Escosura, 2021). Through the creation of this new database we hope to give important historical context to sustainability debates in the present.

There is great interest from international organisations and policy makers in how the management of natural resources affects human wellbeing (e.g., (Atkinson, 2015). For example, the 2021 *Dasgupta Review* argues that 'in order to judge whether the path of economic development we choose to follow is sustainable, nations need to adopt a system of economic accounts that records an inclusive measure of their wealth'. The concept of *Inclusive* (or *Comprehensive*) measures the value of produced, natural, and human capital in a country. Wealth includes all assets from which people can obtain well-being, either directly or indirectly. Changes in wealth per capita, whether positive or negative, are indicators of sustainable or unsustainable development (Hanley et al., 2015). This conceptual approach has been adopted by both the UN Environmental Programme (UNU-IHDP., 2012, 2014, 2018) and the World Bank (World Bank, 2006, 2011, 2018, 2021).

The recent Covid-19 pandemic has highlighted how the global economy is vulnerable to 'Global Catastrophic Risks' (Bostrom and Ćirković, 2008). One of the most prominent of such risks is global climate change and its interaction with other risks, such as pandemics (Ord, 2020). The

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[1] Interchangeably known as 'Comprehensive Investment' and 'Adjusted Net Savings'.

fact that widely used methods for measuring economic activity are 20^{th} century constructs (Coyle, 2017; Masood, 2016) and focus on income (GDP) rather than a nation's comprehensive wealth has partially blinded us to these risks. Moreover, there is now a growing recognition that maximizing year-on-year growth in GDP is unlikely to be a realistic target for the 21^{st} century due to numerous negative environmental consequences (Rockström, 2009; Steffen et al., 2015). The recent IPCC (2021) report included dire warnings of the dangers of future climate change, which, in the main, has been a direct consequence of following a GDP maximization goal. There is now a growing call within the economics profession for changes to be made to how we measure economic activity, economic development, and well-being more generally (Stiglitz et al., 2009, 2018; Polasky et al., 2019). Covid-19 has brought home the importance of our natural capital as Dasgupta (2021) accentuates the link between pressures on biodiversity (part of wealth) and Covid-19, arguing that a greater focus on wealth would have given policymakers warnings about possible risks.

Despite such calls for change, GDP continues to be used, often in policy circles, as the main and often, only, measure of choice to guide decisions designed to increase welfare, in part because it is simple to calculate, but also because it allows country performance comparisons. Politicians can point to GDP growth as a measure of their 'success', both locally and globally.[2] Moreover, the economic history community has shown little engagement with recent developments in the measurement of wealth in its broadest sense. Instead focus has been on extending GDP estimates further back in time (Bolt and van Zanden, 2014; Broadberry et al., 2015). Therefore our estimates of the change in wealth will complement and nuance these research efforts.

Ongoing environmental and developmental challenges compel us to focus on more comprehensive welfare indicators than GDP. These new measures should address long-term sustainability. A recent article in *PNAS* calls for a greater integration of both economics and sustainable development (Polasky et al., 2019). This is the core concept informing the GS approach. Seeing wealth as the foundation of future income and hence welfare, means that changes in wealth (saving/investment) provide an indication of the feasibility of future, sustainable, development paths. This article is the first step to produce such comprehensive welfare indicators, focusing more on stocks (e.g., wealth), including natural capital, which provide forthcoming generations with the capabilities to increase their future well-being, rather than on flows (e.g., income), conventionally measured by GDP, which simply measure annual outcomes without recourse to their long term implications.

The historical focus is necessary to provide evidence as to whether past policies and choices, guided by GDP as a welfare enhancing measure, have maximized (or even increased) well-being,

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[2] Surprisingly, the Agenda 2030 has settled enormous goals such as reducing poverty and clean energy sources, but there is not mention to change our welfare indicators

sustainably. Historical data and outcomes provide our only measures to test the GS approach. Furthermore, historical data would enhance current metrics and provide a deeper understanding of natural capital, human capital, technological change, and environmental degradation in the long run, to guide policy for the future.[3] Much of the current work on environmental economics considers uncertain, unknown futures, (scenarios or predictions), which may simply never exist.[4] However, insights and data from the past can test alternative modelling approaches to inform policymaking in the present and the future. Fenichel et al. (2016) argue that a better understanding of how past changes influence present sustainability outcomes, can be used to forecast the impact of future changes in sustainability.

If GS methods are to inform sustainable social, economic, and environmental futures, they should, as a minimum, be able to explain the past. We will therefore analyse whether historical experiences can explain variations in past and current levels of comprehensive/inclusive wealth within and across countries and what future sustainable development prospects would look like. If the GS concept is to complement or replace other indicators, it requires evidence which includes long run estimates for a wide range of countries. However, there are a lack of standardized methodologies across and within country studies of GS (Hanley et al., 2015).

2 Economics of Sustainable Development

By the early 1990s the phrase Sustainable Development had become 'pervasive' and was 'the watchword for international aid agencies, the jargon of development planners, the theme of conferences and learned papers, and the slogan of developmental and environmental activists' (Lélé, 1991). However, a clear definition of the phrase was elusive as there were (and are) several, sometimes contradictory, definitions (Pezzey, 1992; Dietz and Neumayer, 2007).[5] The 1987 *Brundtland Report* is one of the most widely cited interpretations of Sustainable Development (SD) as a concept (Schubert and Láng, 2005). The *Brundtland Report* defined it as follows:

> Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations

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[3] Recent studies are going in the same direction, such as the *Dasgupta Review* and the inclusion of Natural Capital in UN accounting

[4] climate change uncertainty has received increasing attention since the 2000s (Tol, 2003)

[5] SD is inherently interdisciplinary and, as Qasim (2017) shows, this leads to a wide engagement with the concepts and and development of metrics to assess it.

> imposed by the state of technology and social organisations on the environment's ability to meet present and future needs' (World Commission on Environment and Development, 1987, p.43).

The *Brundtland Report* definition therefore has inter- and intra- generational equity considerations and has been the jumping off point of economists engaging with the concept of SD. For example, Asheim (1994) sees SD as an inter-generational equity issue and defines SD, following along the lines of Hartwick (1977), 'as a requirement of our generation to manage the resource base such that the average quality of life that we ensure ourselves can potentially be shared by all future generations'. Whereas Pezzey (1992) defined SD as 'non-declining utility of a representative member of society for millenia into the future'. The former definition has become interpreted as a capabilities-based and the latter as an outcome-based definitions of SD (Hanley et al., 2015). The capabilities-based approach views a SD path of an economy as one where the (per capita) real values of changes in capital stocks are non-negative (i.e. constant or increasing). Whereas the means-based approach views a SD path as one where utility or consumption per capita is non-declining. Dasgupta (2001) illustrates the relationship between both approaches and shows how comprehensive wealth, in particular the change in wealth, equates to future well-being.[6]

This approach to sustainability links future well-being with changes in capital stocks (Pearce and Atkinson, 1993; Pearce, 2002). Wealth is seen as the foundation of future income and hence welfare (Weitzman, 2017), as changes in wealth (saving/ investment) provide an indication of the feasibility of future, sustainable, development paths. The GS approach to sustainability rests firmly on the so-called Hartwick (1977) rule, as this shows how consumption can be constant over time by re-investing rents from natural resource extraction into other forms of capital (i.e. man-made or human). One of the attractions of the GS is that, under certain assumptions, it can be used to assess both the capabilities-based and the outcome-based approaches to SDHanley2015. Another attraction is that it is firmly grounded in the system of national accounts (SNA) framework and can be used to measure and compare countries in a consistent manner.

Dasgupta defines (*comprehensive*) wealth in terms of manufactured capital, human capital, natural capital, and knowledge (Dasgupta, 2001, p.147).There is a further distinction within this literature in terms of how one perceives aggregate capital. One approach being that SD requires non-declining total wealth (weak sustainability) and another where SD requires non-declining natural capital (strong sustainability). The first approach, effectively extensions of the Solow (1956) neoclassical growth model to incorporate exhaustible resources (Solow, 1974; Dasgupta and Heal, 1974; Stiglitz, 1974), assumes perfect substitutability between different types of capital and the

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[6] This is also elucidated in Arrow et al. (2012).

monetisation of natural capital, so a \$1 decrease in the value of natural capital can be compensated by a \$1 increase in human capital for instance. Whereas the latter approach deems that a decrease in a physical unit of natural capital can not be replaced by increase the quantity of other forms of capital (Costanza and Daly, 1992).[7] As the degree of substitutability is difficult to establish empirically (i.e. (Markandya and Pedroso-Galinato, 2007; Cohen et al., 2019), how one chooses to approach sustainable development, from a weak or strong perspective, is a matter of belief. However, if a country fails a weak sustainability test, such as negative genuine savings, it will in all likelihood also fail a strong test as well (Hamilton and Clemens, 1999).

2.1 How does SD relate to traditional economic history research initiatives

How we measure the *wealth* of nations is a key aspect of modern economic history. Although, as Alfred Marshall insightfully observed, 'estimates of the wealth of other countries have to be based almost exclusively on estimates of income' (Marshall, 1920, p.197). Modern national accounting dates to the 1930s (Coyle, 2015; Field, 2019) and had focused on measuring income (Maddison, 2004).

Gross Domestic Product (GDP), the measure of final goods and services produced within a country in a given time period, is the most widely used metric of economic activity (Stiglitz et al., 2009). In effect, GDP is a measure of a nation's income. The appeal of GDP lies in its international comparability and consistency, efforts at consistent approaches to national accounting date to the early twentieth century (Coyle, 2015; Field, 2019). The UN System of National Accounts are a globally recognised framework for measuring GDP and are periodically updated. As the limitations of GDP are widely known, such as its treatment of environmental degradation and climate change, (e.g., see Stiglitz et al. (2009)), several attempts have been made to adjust and expand SNAs to incorporate wider aspects of sustainability, including natural capital (Brandon et al., 2021).

Much of the work of economic historians since the 1960s has been in quantifying long-run economic growth by estimating historic GDP (Crafts, 2009). Part of the initial rationale for these research endeavours was due to the increased interest in economic development as a sub-field of economics. Historical data was able to contextualise both modern and historic development experiences (Arndt, 1987). This work has been continued to the present day by the *Maddison Project* which collects and collates data on GDP over time and space (Bolt and van Zanden, 2014) and these have been widely used by growth economists (Deaton and Heston, 2010). The main extensions

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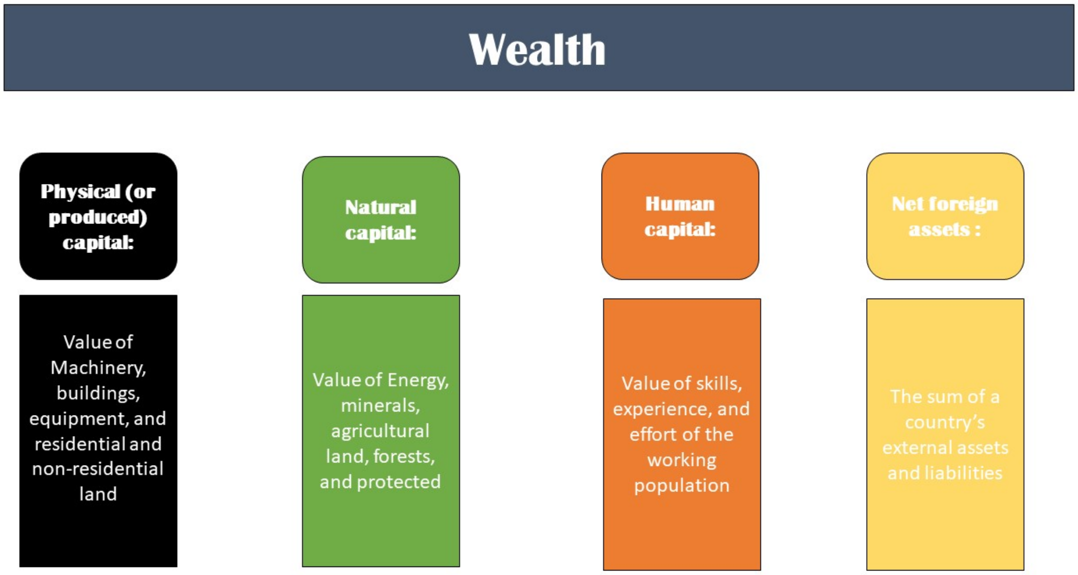
[7] Costanza and Daly (1992) refer to total natural capital which is renewable plus nonrenewable natural capital. Ecosystems are the example given for renewable (or active) natural resources as they can yield a service when harvested (timber) or when left in place (e.g. erosion control). Whereas nonrenewables are passive in that they yield no service until they are harvested.

of the latest *Maddison Project* have been to extend (consistent and comparable) estimates of GDP pre-1850 for a more geographical diverse array of countries. With one of the major contributions of this exercise has been in the realm of identifying the timing of the 'Great Divergence' between Europe and Asia.

In addition to quantifying growth experiences, economic historians have attempted to explain the underlying drivers of growth Crafts (2009). Here economic historians availed of contemporary growth theory, namely the work of Solow (1956, 1957) which showed how technical change was a major driver of growth in the United States. Long-run perspectives on the causes of growth (and slowdown) required development and collation of long-run series of GDP, as well as capital and labour. [8] The results from this research agenda showed how technical change was the main driver of economic growth over time in western countries, although experiences in Asian countries have highlighted the importance of capital accumulation (deepening) Crafts and Woltjer (2021).

Figure 1: Components of Wealth



At the most basic, the economics of SD is more welfare orientated and focuses on changes in wellbeing (proxied by per capita consumption) rather than GDP growth, it focuses on net savings(investment), and places greater emphasis on natural resource stocks (Ferreira et al., 2008). The GS approach therefore relates to both the idea of wealth accounting, as it is an indicator of how a nation's total wealth changes year-on-year (i.e. a flow) (Hamilton and Hepburn, 2017; World Bank, 2018), and income accounting (i.e. GDP), as it is is built upon a foundation from the SNAs (Hanley

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[8] For example, see Maddison (1987)'s seminal article which placed economic slowdown in the 1970s and 80s in historical context (this was updated in Maddison (1996).

et al., 2015). In accounting terms, while both GS and GDP are flows, the distinction between them is clear: GS is a measure of the change in the stock of wealth, whereas GDP is a measure of income that is derived from the stock of wealth. One such approach focuses not on GDP (income) but instead on total wealth (or capital). The intuition here is that wealth unpins future well-being within an economy, as wealth (capital) broadly defined is required to generate future income streams (i.e., GDP) (Arrow et al., 2012) - e.g. see Figure 1. This approach has been the hallmark of recent efforts by the World Bank and the UN (e.g., see (World Bank, 2006, 2011, 2018, 2021; UNU-IHDP., 2012, 2014, 2018).

Placing greater historical emphasis on wealth therefore brings the SD literature into the orbit of what Crafts refers to as ""capital-fundamentalist" view of economic development' (Crafts, 2009, p.214). By this Crafts was referring to the once influential view of Rostow (1959, 1990) which emphasised a doubling of investment rates and a sustained ' an annual rate of *net* investment of the order of, at least, ten per cent' or more (emphasis added). This was seen as a key criteria for 'take-off', i.e. modern economic growth. This effectively channelled the Keynesian growth models of Harrod (1939)- Domar (1946). However, this view is 'now seen as inappropriate' (Crafts and Woltjer, 2021). While the work of Solow and others disputes the centrality of capital accumulation. It is this emphasis on 'net' is something which relates it back to the modern focus on wealth, as the focus of wealth is net and not gross wealth.

3 Methodology

GS, also known as adjusted net saving (ANS), measures the "true" (or "genuine") rate of saving (investment) in an economy after taking into account depreciation of fixed capital, investment in human capital, depletion of natural resources, and damages caused by pollution. Genuine savings, the name used in this article, it is an indicator that aims to assess an economy's sustainability based on the concepts of Environmental Economic Accounting (SEEA, 1993, 2003, 2014).

We have largely followed Hamilton and Clemens (1999) and the World Bank (2006, 2011) methodology[9] for calculating GS by estimating a range of increasingly-comprehensive measures of year-on-year changes in total wealth over time.[10] We construct the following indicators to display and distinguish several degrees of sustainability - also outlined in figure 2:

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[9] This is outlined in Bolt et al. (2002)

[10] Recent work of the World Bank (2018, 2021) has focused primarily on wealth estimates and estimate the change in wealth as a predictor of sustainability. There is only one study which attempted to do this using historic data but viewed GS as a more reliable indicator of sustainability (McLaughlin and Hanley, 2014).

The main formula for calculating GS is as follows:

$$GS = I - \delta K - n - \sigma(e) + m \tag{1}$$

Figure 2: Genuine Savings Calculations

Where I is investment, δ K is traditional depreciation of fixed capital, n are resource rents, σ is damage cost from pollution[11], and m is human capital.

Over the past 25 years, starting with Pearce and Atkinson (1993) and Hamilton and Clemens (1999), there have been a series of Genuine Savings estimates for a host of countries. The time period covered by most estimates range from the 1970s to the present.

Studies have tended to trade off scale and scope, with studies focusing on individual countries being richer in data quality but not directly comparable across countries. Definitions of metrics have also varied with 'green' and 'genuine' savings measures commonly constructed and used interchangeably (see Hanley et al. (2015) for a review of the empirical literature). There are several studies that have calculated GS for shorter time periods. Some have explicitly compared estimates of GS with measures of Green national product (Pezzey et al., 2006; Mota et al., 2010). Others have focused on expanding measures of GS to incorporate additional pollutants, for example Ferreira and Moro (2011) estimate GS for Ireland from 1995-2005, McGrath et al. (2019) build on this work by incorporating additional pollutants and estimate GS for Ireland from 1990-2016. (Pezzey et al., 2006; Mota and Domingos, 2013; Ferreira and Vincent, 2005; Pezzey and Burke, 2014) There have

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[11] Emissions minus dissipation

been several estimates of historical GS, the pioneering work was by Rubio (2004) who estimated GS for Mexico and Venezuela from the 1920s to the 1990s. Later work looked at the experience of developed countries over more than a hundred years, with a focus on Germany, Sweden, the UK, Australia and the US (Lindmark and Acar, 2013; Greasley et al., 2014; Hanley et al., 2015; Greasley et al., 2017). More recent work has analysed GS for countries in the twentieth century (Qasim et al., 2020; McGrath et al., 2021)

Pezzey and Burke (2014) argue that the scale that GS should be analysed is at a global level. Their contribution is to aggregate national level estimates of GS and incorporate different differences in carbon pricing at a global level. The global scale approach was taken by Blum et al. (2017) who incorporated historical estimates of the above mentioned developed countries with estimates for several Latin American countries. Our database expands on this work.

3.1 Net National Savings and Investment

The starting point for World Bank (2011) in calculating GS is to estimate National Savings as a residual from GDP minus total (private & government) consumption. Then estimates of depreciation are subtracted from this to calculate net savings rates.

Maddison (1992) was a pioneer in the study of historic savings rates, calculating historical savings rates for 11 countries from the 1870s through to the 1980s. However, these are gross savings rates and there is no allowance for depreciation.

For our study we have incorporated net investment as an alternative to net savings. Here net investment, including overseas investment, reflects changes in a country's physical assets. Estimates of net investment were readily available for various countries, but for some of them we have estimated net investment using gross investment and consumption of fixed capital, or simply annual depreciation of assets (see appendix for a detailed list of sources used). In a previous study of Latin American 'Green' investment over the period 1973-1986, Vincent (2001) lamented the quality of conventional measures of reproducible capital in Latin American countries. In order to overcome this concern, we make use of capital stock estimates for Latin American (Tafunell and Ducoing, 2016) and the investment series produced by Tafunell (2013).

3.2 Natural Capital

To account for the depletion of natural (renewable and non-renewable) resources we subtracted the rent from the depletion of natural resources, using gross revenues minus average costs of depletion, from net investment.[12] For European countries, the bulk of gross revenues from resource extraction originate from the extraction of coal, and for more recent times from oil and natural gas (e.g., Great Britain). We also considered other resources, but the quantities by and large are negligible compared with the accumulation of other assets. For the US and Australia, two resource abundant developed nations, we included data on coal, oil and gas as well as metal and mineral ores, as well as changes in forestry. For Latin American countries, resources considered include metal and mineral ores and fossil fuels. Important sources of natural capital depletion are petroleum (Argentina, Colombia, Mexico), gold (Brazil, Colombia), silver (Colombia), coal (Brazil) and copper (Chile).

3.3 Human capital

It is possible to measure human capital created by investment in education and skills (Dasgupta, 2001), however within existing national accounting frameworks expenditure on children's education (via teacher salaries) is considered to be consumption, while some element of capital spending on school building is included in capital formation this is a small share of annual education expenditure (Hamilton and Clemens, 1999). To address this we use education expenditure to proxy the accumulation of human capital to obtain a more inclusive measure of a country's assets. Admittedly there are limitations to this approach as it is known that education does not perfectly equate with human capital, however, alternatives measurements of human capital stocks, such as discounted life-time earnings, are not available for all countries over the whole of our sample. Furthermore, an additional limitation of this approach is that education expenditure as a proxy for human capital accumulation makes no allowances for appreciation of (e.g. on-the-job training & experience) and depreciation (aging & mortality) of human capital. Moreover, this approach does not account for international migration whereby migrant recipients benefit from the human-capital embodied in immigrants and developing countries may experience losses in human capital through emigration.

3.4 Technological progress and the value of time

Technological change has been an important concept in the theoretical literature (Weitzman, 1997), but there are a number of challenges incorporating a measure of technology into empirical studies

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[12] We used the market value of extracted renewables and non-renewable resources as well as the extracted quantities to compute the gross revenues. The average extraction costs were estimated using labour requirement and the average wage of labourers. Similarly, estimates of the value of the change in timber stocks by country was based on changes in area covered with forests, the average quantity of timber per m^3 and the market value of timber. For more recent periods the FAO (2010) provides estimates on the cubic quantities of timber on a given surface area; it is likely that applying this methodology on historical periods overestimates historical forest stocks since we implicitly assume than the high modern tree planting density has existed throughout the period under observation.

(such as how to measure technology, i.e. R&D, patents, energy intensity, total factor productivity?). Pezzey et al. (2006); Mota and Domingos (2013) and Greasley et al. (2014), have used changes in TFP as an indicator of technological progress and incorporated this into the genuine savings framework through the net present value of TFP's contribution to future GDP growth.

We added a proxy for the accumulation of technology to take into account intangible assets (Weitzman, 1997).Weitzman suggests that this adjustment may be in the region of 40 per cent of Net National Product. Thus, omitting a technological progress measure would mis-state the degree of sustainability of an economy. In relation to technological progress, although many of the general purpose technologies were invented in the late nineteenth century (telephone, electricity, combustion engine), it was not until the twentieth century that they were adopted en masse and in many cases this meant the use of new natural resources that had been overlooked in the past (oil and natural gas for example) but in turn this lead to more efficient use of resources (e.g. improvements in fuel efficiency) e.g. see Gordon (2016). Therefore, we have incorporated the effects of exogenous technological progress in our measure of GS by including the present value of TFP growth. We calculate TFP assuming a standard Cobb-Douglas production function with capital and labour measured in man-hours.

$\mathrm{Y} = \mathrm{AL}^{(\alpha)}\ \mathrm{K}^{1-\alpha}$

Where Y equals income, L is labour (measured in man hours) and K is the capital stock. A denotes TFP which is estimated as a residual from this calculation. Trend TFP was used to estimate the value of exogenous technological progress. Following Pezzey et al. (2006) and Greasley et al. (2014) we calculate the present value of future changes in trend TFP over a 20 year time horizon. This is done to capture the uncertainty over the duration of the value of technological progress.[13]

TFP is a central piece of the puzzle to assess sustainable development; this metric, however, is somewhat in conflict with other components of GS. TFP is related to innovativeness, intangible assets, institutions and social capital, and as a consequence the incorporation of TFP brings the risk of 'double-counting' the effects equally associated with technology and human capital. Baier et al. (2006) find that incorporating a measure of human capital reduces the size of the residual; Similarly, Manuelli and Seshadri (2014) argue that better measurements of human capital quantity and quality can further reduce TFP. There is therefore reason to believe that the overlap between human capital accumulation and the value of technology accumulation leads to a slight overestimation of total

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[13] Arrow et al. (2012, table 3) incorate a measure of TFP but do so by adding the current TFP growth rate to the per capita growth rate of Total (Comprehensive) Wealth. However, this approach only adds 1 year and does not take account of the value of time as an uncontrolled capital stock. The choice of 20 years follows Pezzey et al. (2006) and Greasley et al. (2014). Using the case of Argentina as an example, where the present value of TFP is 10.12 per cent over 20 years, if a shorter hoirzon (10 years) is used this is reduced to 8.45 per cent of GDP and if a longer horizon (30 years) is used this increases to 15.87 per cent of GDP. Therefore, by chosing a 20-year horizon we err on the side of underestimation of the value of technological progress.

capital formation. Data limitations and availability prevent us from fully disentangling human capital and technology. We therefore opt to incorporate an unadjusted TFP series in our estimates, however, in the results section we illustrate the effect of TFP appended to Green investment to avoid the possibility of double counting as education expenditure is included in GS.

Although as Bakker et al. (2019) note, 'TFP growth is not a synonym for technological change' and TFP growth may in fact be an over/under estimate of the contribution of technological change to labour productivity growth owing to a misspecified production function.

3.5 Pollution

Lastly, we incorporate a range of prices related to damages from carbon dioxide emission in our global estimates. Carbon dioxide is a greenhouse gas (GHG) with lifetime of up to 200 years in the atmosphere and accounts for 75 per cent of global warming potential (Stern, 2007, table 8.1).

The crucial factor is that it is a stock pollutant in that the annual emissions add to the existing concentration in the atmosphere and each unit of emissions increases the marginal damage cost of the pollutant in the future (Kunnas et al., 2014). To account for CO_2 in our sustainability indicator we used the total amount of carbon dioxide emitted and estimates of the social costs of carbon derived from the wider literature. There are a range of price estimates that we have incorporated, such as the constant \$20 tonne carbon cost of the World Bank metric, \$29 t/c from Tol (2012), \$110 t/c from the Stern Review (Stern, 2007). However, the results presented below purposely utilise the more recent estimates of the social cost of carbon by Pezzey and Burke (2014). The first price, \$131 t/c, estimated from a DICE model recalibrated to assume that it is economically optimal to control emissions such that warming may be limited to an agreed target of 2 C and a significantly higher price of \$1455 t/c which assumes that no controls of CO2 emissions are implemented.

We choose to highlight these contrasting prices as our study shares similarities with Pezzey and Burke (2014) in that we also attempt to determine if the world is on a "global" sustainability path. These prices are discounted over time as suggested by Tol (2012) and as illustrated by Kunnas et al. (2014).[14]

3.6 Discounting

Add a table of different discount rates by country

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[14] For a more comprehensive overview of data sources used see the data appendix as well as Blum et al. (2013), Camacho (2014), Greasley et al. (2014), Greasley et al. (2017); Höfeler (2014), Klenk (2013) and Mennig (2015).

3.7 International dollars

In past work the World Bank (2006) made comparisons of wealth between countries using market exchange rates. While noting variance in wealth per capita between developed and developing countries, some of this was attributed to the use of nominal exchange rates (World Bank, 2006, p.17). The most recent World Bank (2021) attempts to address this by incorporating Purchasing Power Parities, these are derived from the International Comparison Programme (Deaton and Heston, 2010). The issue here is that the prices collected are not necessarily related to the capital stocks that are being measured in wealth accounting and were originally intended to be used in comparing income across countries. It is acknowledged that 'using PPPs in wealth accounting requires several theoretical and empirical considerations, none of which have been exhaustively addressed' (World Bank, 2021, p. 83). These issues are whether using PPP is appropriate in a wealth accounting context, what level of PPP should be used, and how to construct a constant value series based on PPPs.

While we have reservations about applying PPPs that are derived for another purpose, using a PPP based series enables comparability across space and time. All units have been deflated using national GDP deflators and have been converted into purchasing power adjusted international dollars following Maddison (2001) and Bolt and van Zanden (2014), expressed as Geary-Khamis dollars ($) in the figures below.

3.8 Limitations

A limitation of the construction of GS as outlined above is that it only covers quantifiable indicators that can be approximately expressed in monetary units. Thus GS overlooks non-market environmental goods and services and as a result the GS metric excludes developments in other pollutants such SO_2 and NOx, and developments in biodiversity and ecosystem services. Historical estimates of SO_2 and biodiversity are available but these indicators are difficult to incorporate in an augmented long-run GS metric until a compromise estimate of their economic value over time is obtained. The absence of monetary evaluations of these phenomena, however, cannot hide the fact that economic growth seems to adversely affect biodiversity and levels of pollution. The global output of SO_2 increased throughout the twentieth century, with the major share of SO_2 being emitted in North America, followed by Western Europe. Total global SO_2 emissions rapidly rose after World War Two, and peaked around 1980. During the late twentieth century, mainly environmental regulation combined with fuel-saving technologies and a transition away from fuels with a high-sulphur content helped to lower global SO_2 output (Stern and Kaufmann, 1996). Losses in biodiversity are largely the result of changes in land use; the increasing demand for grazing and cropland has encouraged deforestation which in turn resulted in losses in biodiversity. Estimates on the development of biodiversity suggests that Latin America and the US, and the majority of the world's countries experienced losses in biodiversity whereas some countries in Western Europe saw stagnating or even increases in biodiversity.[15] Any future evaluation of the costs of biodiversity loss and SO_2 emissions will lower any sustainability indicator (see **?** for an overview).

4 Historical estimations of Genuine Savings. The new dataset

To elaborate this first version of the Genuine savings historical data base, we have done our own estimations in base to the methodology described in the section 3 plus previous work in the field. As the majority of economic history works or historical data in the long run, the main group of countries studied have been the developed ones. If we classified these countries by the length of the period already estimated, United Kingdom has the longest series of GS thanks to the work of Greasley et al. (2014).

A three country comparison was developed by some of these authors in Hanley et al. (2015). In the case of Germany, the period available is 1850 - 2015 (Blum et al., 2013). France and Switzerland have the twentieth century data from Blum et al. (2017). For Oceania, two articles has extended the World Bank series until 1870 in the case of Australia and 1950 in the case of New Zealand (Greasley et al., 2017; Qasim et al., 2020). Inaki has recently estimated GS for Spain (1950 - 2020), expanding the WB series and including a more robust forestry valuation.

As we have mentioned previously, one GS handicap is the lack of estimation on long span period for developing countries. Some work have been doing in the recent past. Pioneering work by Rubio (2004) was the first to estimate GS for several Latin American Countries, including Mexico and Venezuela, in the twentieth century. Blum et al. (2017) extended these estimates as well as incorporating four additional Latin American countries (Argentina, Brazil, Chile and Colombia). Most recently Labat et al. (2019) estimated a long run series for Uruguay (1875 - 2020).

In the framework of this paper version, we have estimated GS for additional four countries: Japan, Norway, Portugal, and Denmark.[16] Moreover, the Argentinean and Chilean data have

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[15] Stock valuations of global ecosystem services are most notable at the end of our period of study, such as Costanza et al. (1997), who estimated the global value of the entire biosphere to be between $16-54 trillion, and **?**, who updated the Costanza et al. (1997) figures from 1997-2011. However, these stock valuations do not enable us to value changes in ecosystem services in the years preceding 1997. Furthermore, there have been increasing uses of revealed and stated preference methods to value changes in environmental goods and services. However, these studies have not been applied consistently over time and benefit transfers may not be applicable spatially or temporally for all countries in our study.

[16] The Denmark data has been estimated a thesis written by Andrew Pierson.

extended 20 years backwards from the former estimation published in Blum et al. (2017).

A summary of the countries presented in this article and the time span that cover each of the estimations in the table 2. One of the value added of the present paper is the inclusion of more developoing countries, one of the main handicaps in previous GS estimations.

Table 1: Data sources and period covered of Genuine Savings estimations

Country	**Period**	**Source**
Argentina	1900 - 2000	Blum et al. (2017)
Australia	1870 - 2018	Blum et al. (2017)
Bolivia	1890 - 2018	This paper
Brazil	1880 - 2018	Blum et al. (2017)
Chile	1880 - 2000	Blum et al. (2017) + this paper
Costa Rica	1902 - 2000	Pollack + this paper
Colombia	1900 - 2000	Blum et al. (2017)
Germany	1850 - 2010	Blum et al. (2013)
Great Britain	1850 - 2010	Greasley et al. (2014)
France	1900 - 2000	Blum et al. (2017)
Mexico	1900 - 2000	Blum et al. (2017)
New Zealand	1950 - 2000	Qasim et al. (2020)
Norway	1870 - 2000	this paper
Portugal	1900 - 2000	This paper
Spain	1950 - 2010	Iriarte
Sweden	1850 - 2010	Lindmark and Acar (2013)
Switzerland	1900 - 2000	Blum et al. (2017)
Japan	1880 - 2010	This paper
Venezuela	1935 - 1985	Rubio (2004)
Uruguay	1875 - 2015	Labat et al. (2019)
United Kingdom	1765 - 2000	Greasley et al. (2014)
United States of America	1870 - 2015	Hanley et al. (2015)

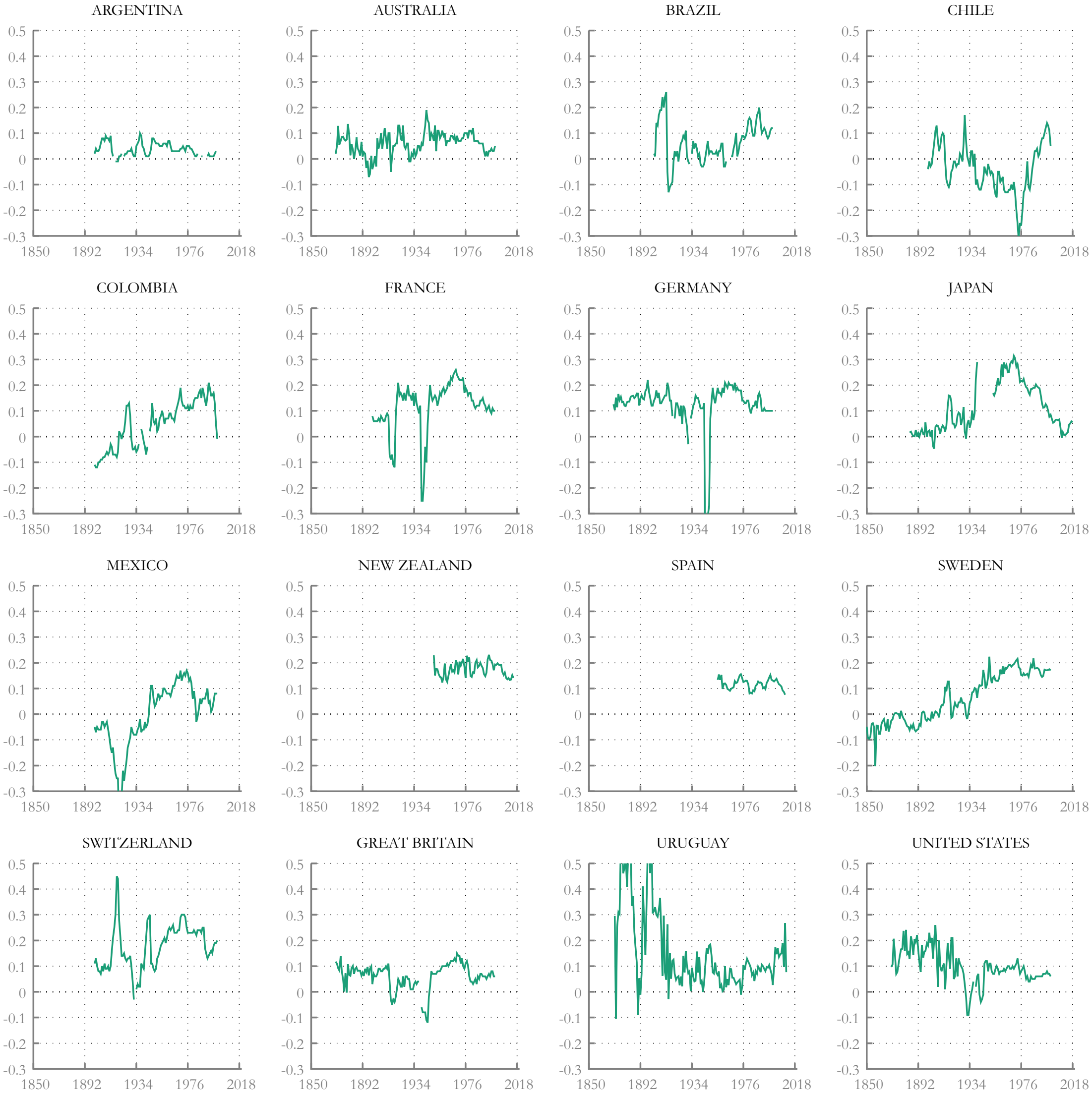

Figure 3: Genuine Savings as share of GDP. 1850 - 2020

Table 2: Discount rates and TFP growth rates

Country	**Discount rate**	**TFP growth rate**
Argentina	2.55	1.66
Australia		1.18
Brazil	4.82	1.87
Chile	4.28	0.88
Colombia	4.63	0.22
Germany		1.91
France		1.23
Portugal		
Mexico	3.12	1.30
New Zealand		
Norway		
Spain		
Sweden		
Switzerland		1.58
Japan		
Venezuela		
Uruguay		
United Kingdom		1.25
United States of America		1.67

5 Discussion

The results for Latin America of this version are summarized in the figures **??** and **??**. As have been emtioned previously in Blum et al. (2017), the development perspectives of Latin America changed radically when we take into account weak sustainability trends, especially for the different accounting we do of the natural resources dependence. The case of Chile become paradigmatic. Between 1950 and 1990 the average GS per capita was negative, meaning that the extraction of natural resources, mainly copper, was not *re-establish* trough new investments in human capital or non-residential fixed investment. The case of Argentina become paradigmatic too. Argentina was considered the richest country of Latin America until the 1970's with irruption of Venezuela and its oil wealth. However, and a feature similar to Chile, the exploitation of Natural Resources does not become in a sustainable investment in human capital or net national savings. The trend in the first half of the twentieth century is positive, but not specially different than Brazil and Colombia.

Labelling on the plot seems a bit off[17]

- If has both GS & pollution
- Figure 3 incorproates CO_2 emissions

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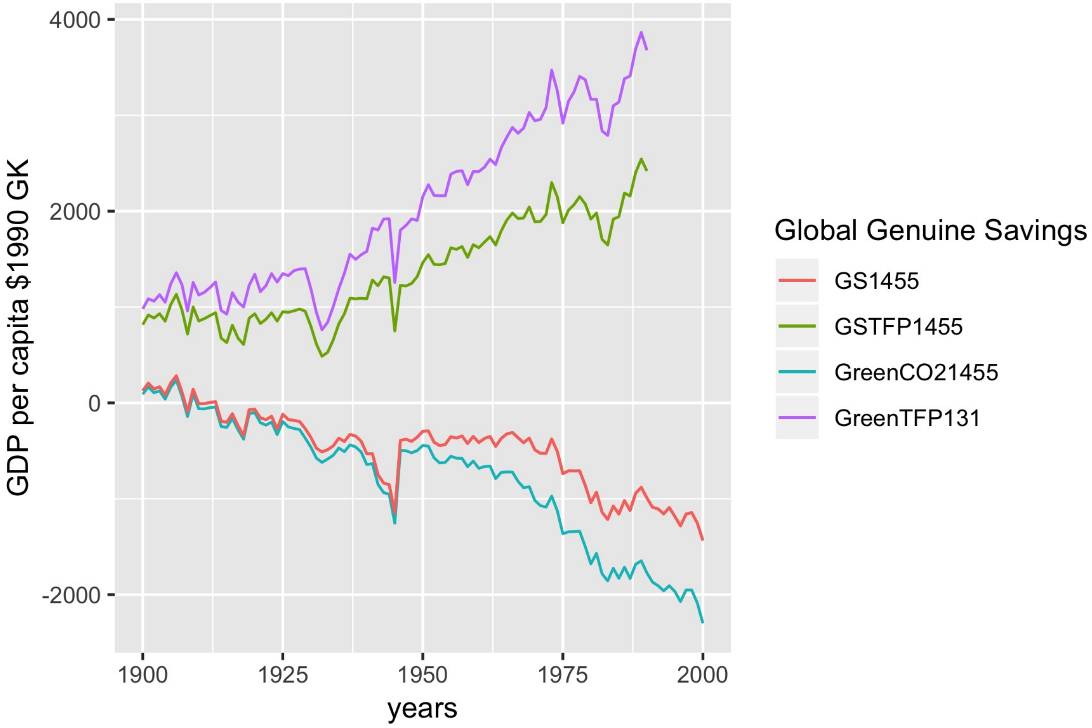
[17] Yes, but the graph 3 are the GS without TFP

Figure 4: Global GS estimations with two different CO_2 cost prices



- How CO_2 emissions are priced dictates the signal we receive

- Discuss global

- Discuss GS v GDP

Considering GS alone, Figure 3 shows all countries using the same scale. Clear trends emerge of savings rates that average X and range between Y & Z.

Some countries experience periods of negative GS, such as Brazil, Australia, France, Germany, Britain, US, Uruguay, and these negative episodes tend to coincide with well known macro shocks such as Wars and the Great Depression. Others, such as Sweden & Mexico, start the period experiencing negative GS and transition to positive GS. Of the countries two were notable outliers, Chile & Uruguay; the former for persistent negative GS, the latter for its high initial rates of GS and the volitaility of the measure. Of the countries in the sample, only New Zealand & Spain do not show signs of negative GS.

How do these figures compare to standard narratives surrounding economic growth? Figure X plots GS & GDP% and GDP per capita. Inclusion of TFP is an important consideration.

Pop growth

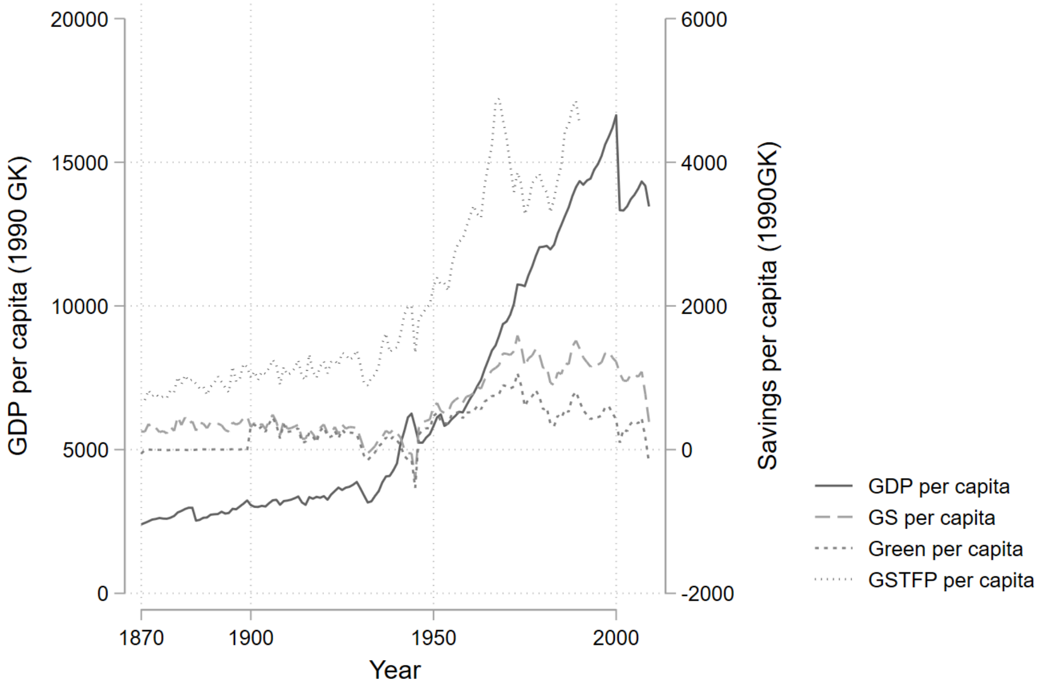


Figure 5: GDP per capita and Savings measures per capita. 1850 - 2020

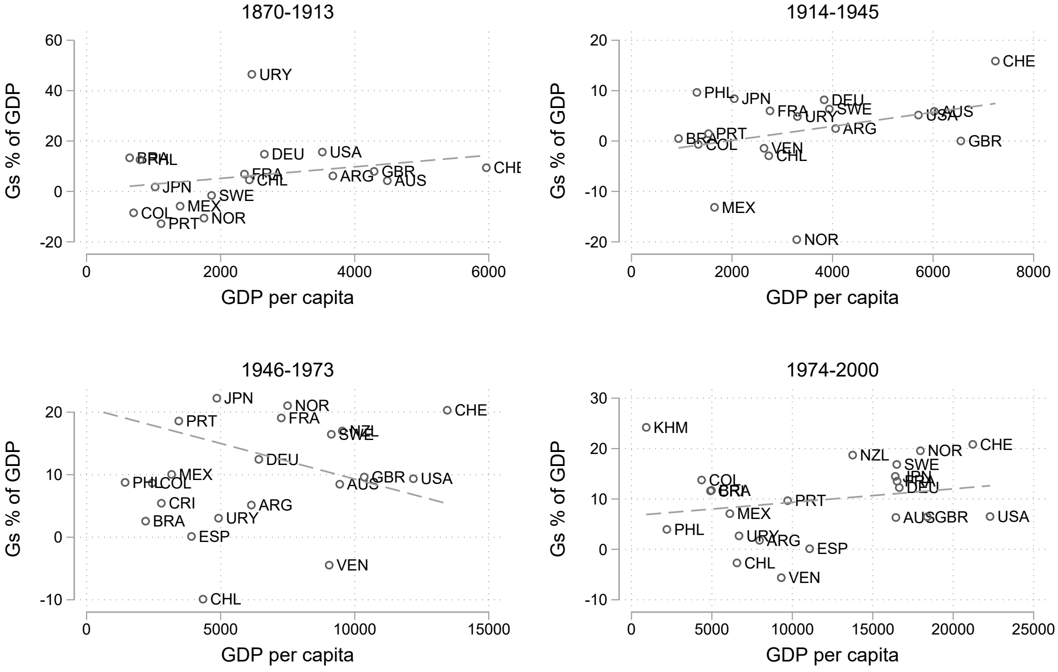


Figure 6: Global GDP growth and savings rates. 1870 - 2000

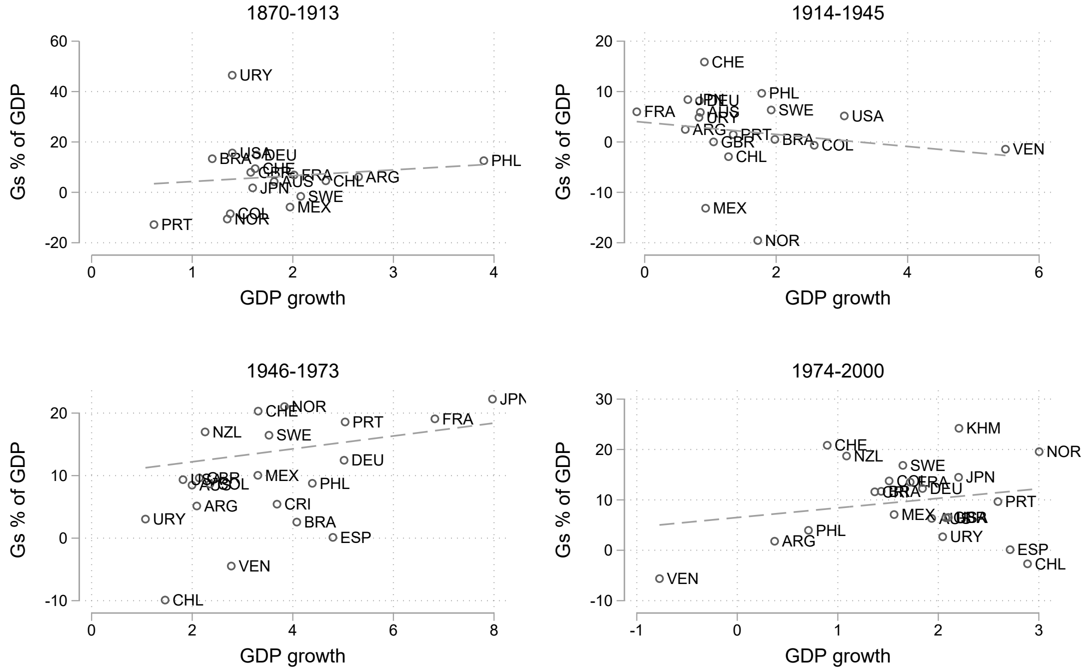


Figure 7: Global GDP growth and savings rates. 1870 - 2000

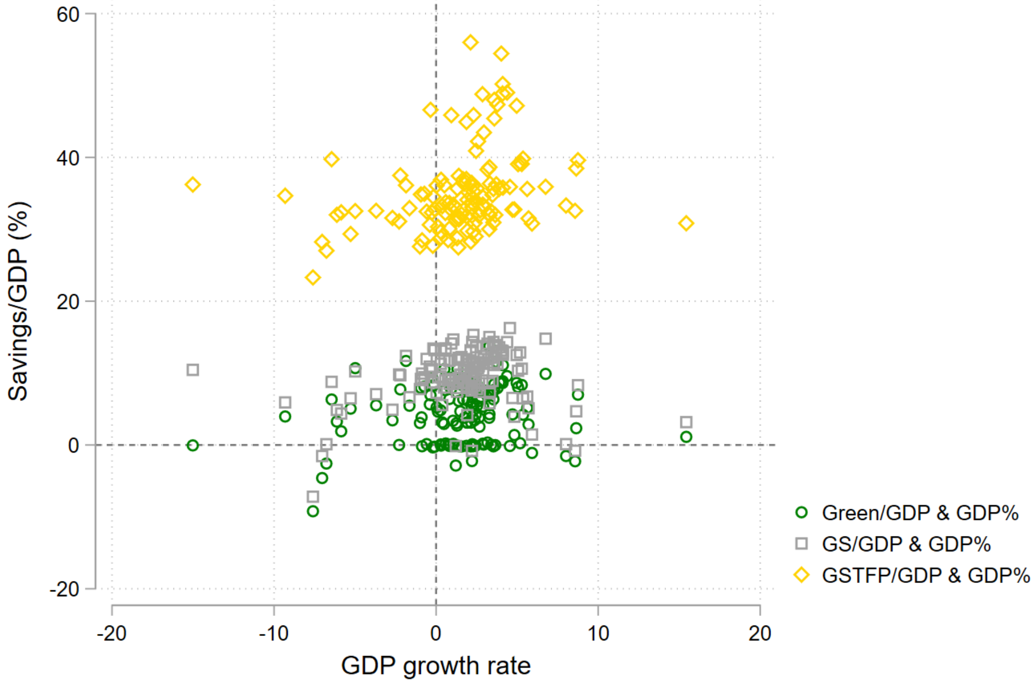


Figure 8: Global GDP growth and savings rates. 1870 - 2000

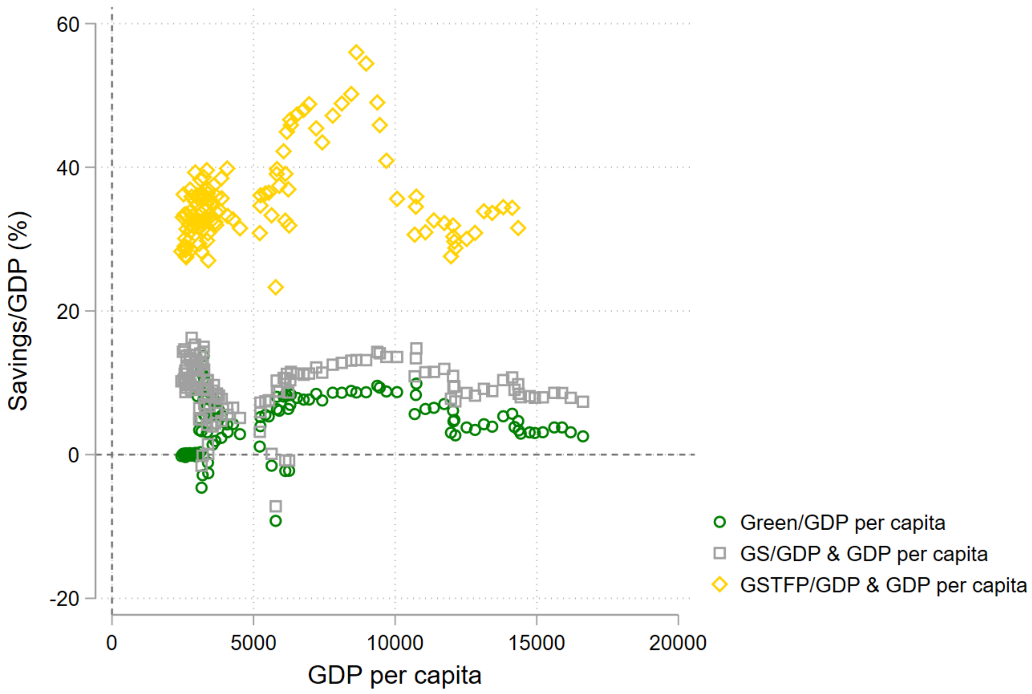


Figure 9: Global GDP per capita and savings rates. 1870 - 2000

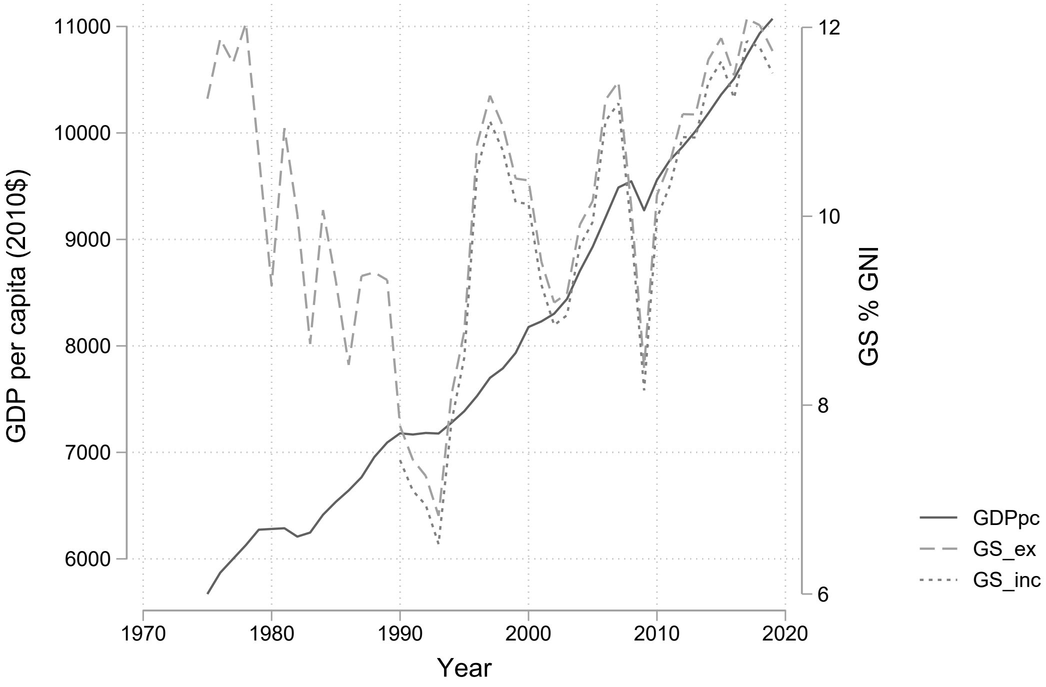


Figure 10: World GDP per capita and GS. 1970 - 2020

Figure 11: World GDP per capita and GS

5.1 Comparison with ANS from World Bank Data base

6 Conclusions

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Data Appendix

Appendix

The data it could be downloaded from the following link:
https://www.genuinesavings.org/data. It is in several formats (Stata, Gretl, Excel, csv and R) and the reference should be this paper if there are more than 5 countries used in the study. If the number of countries in your study is lower to five, please use the list of references for each country available in the data set.

The code to reproduce the graphics and some of the estimations is available at further request: cristian.ducoing@ekh.lu.se

Sources

Australia

The GS estimations for Australia are from Greasley et al. (2017)

Great Britain and United States

The GS estimations of Great Britain and United States are from Greasley et al. (2014); Hanley et al. (2015)

France

Note that all statistics use for this study refer to 'European France', excluding Algeria and other (former) colonies. GDP and GDP deflator: Pre-1982 data on French GDP is available from Toutain (1987) and Flora et al. (1983). GDP levels for later periods are taken from official Statistical Yearbooks of the French National Institute of Statistics and Economic Studies (INSEE). Data for the period between 1914 and 1920 can be found in Hautcoeur (2005). For the period 1939 to 1945 data on French GDP is taken from Occhino, Oosterlinck and White (2006). A GDP deflator was constructed using data from Mitchell (2007), Lévy-Leboyer and Bourguignon (1985) and the INSEE. Net investment: net fixed capital formation and changes in inventories for the 19th and for the beginning of the 20th century is provided by Lévy-Leboyer and Bourguignon (1985). The gap between 1914 and 1945 was estimated using Markovitch (1966) who reports investment and destructions during the wars as well as investment in the inter-war period and Carré, Dubois and Malinvaud (1972). For the period 1945 to 2000 data on inventory changes and net fixed capital formation was taken from the INSEE, the World Bank (2014) and the United Nations UNSD (2014) investment statistics. Data on net overseas investment is provided by Banque de France (2014), which provides a section with historical time series going back to the 18th century. Private consumption was taken from Flora et al. (1983), the INSEE, Baudrillard (1996), Beaupré (2004) and Asselain (1984). Forestry: For the second half of the 19th century a complete time series of French forest stocks and the French timber market was not available. In France, forestry management only developed to a high standard at the end of the 19th century. Therefore, linear interpolation was used for the construction of the time series between 1850 and 1890 as there was only data available in five year intervals. Information on French forestry stocks were taken from Zon (1910) and Zon and Sparhawk (1923), Cinotti (1996), Koerner et al. (2000) and from the statistical database of the FAO (2014). Non-renewable resources: Detailed data on French mining activities, including the number of employees in the mining sector, extraction quantities and market prices, can be found in the yearly publications of the French mining sector called Les Annales des Mines, a series of which the first issue was published in 1794. Additional information are provided by the statistical yearbooks of the INSEE, especially by the issues called Annuaires Rétrospectifs, which include data going back until the 18th century, and by Mitchell (2007). To assess the costs of depletion the number of employees in the mining sector and their average wage were used. Data on the labour force is provided by Les Annales des Mines and the INSEE. Wages of mining workers are reported by the INSEE, Simiand (1907), Marchand and Thélot (1997) and Diebolt and Jaoul-Grammare (2008). Education expenditure is provided by Diebolt (1995, 2000). For the post-1994 period World Bank (2014) data on education expenditure was used. Carbon emissions were taken from Andres et al. (1999) and Boden, Marland and Andres (1995). This data is available online on the website of the Carbon Dioxide Information Analysis Center, an organization within the United States Department of Energy, under http://cdiac.ornl.gov/CO2_Emission/timeseries/national. Total Factor Productivity: labour hours worked and real GDP is taken from Greasley and Madsen (2006). Information on capital stock can be found in Guerrero (2013). Factor shares used were from Greasley and Madsen (2006), capital share is 0.60 and labour 0.40. A Kalman filter of the TFP growth rate was estimated and this was forecast using an ARIMA (2,1). Discount rates: Data on historical interest rates and government bond yields were taken from Homer and Sylla (2005) and Banque de France (2014).

Germany

GDP and GDP deflator: Pre-1975 data on German national product is available from Flora et al. (1983) and Hoffmann et al. (1965). GDP levels for later periods are taken from German Statistical Yearbooks (1999, 2008). Missing periods 1914-1924 and 1940-1949 were estimated using Ritschl and Spoerer's (1997) GNP series. A GDP deflator was constructed using data from Hoffman et al (1965), Mitchell (2007) and the United Nations Statistical Division (2013). Net investment: Net investment from 1850-1959 is provided by Hoffmann et al. (1965). We estimated the gap during 1914-1924 using Kirner (1968) who reports investment in buildings, construction, and equipment by sector for the war and inter-war periods. The period 1939 to 1949 was estimated by using data on net capital stock provided by Krengel (1958). To estimate investment during 1960 to 1975 we used Flora et al.'s (1983) data on net capital formation. For the period 1976 to 2000 we use official World Bank (2010) and United Nations (2013) investment statistics to complete the series. Data on the change in overseas capital stock and advances is provided by Hoffmann et al. (1965). Gaps during war and inter-war periods were estimated using information on the balance of payments provided by the German central bank (Deutsche Bundesbank, 1998, 2005). Remaining missing values were estimated using trade balances as a proxy for capital flows (Deutsche Bundesbank, 1976; Flora et al., 1983; Hardach, 1973). Private Consumption is taken from Flora et al. (1983), German Statistical Office, downloadable under www.gesis.oreg/histat, Ritschl (2005), Abelshauser (1998), and Harrison (1988). Forestry: Zon (1910), Zon et al. (1923), Hoffmann et al. (1965), and Endres (1922). Non-renewable resources: Fischer (1989) and Fischer and Fehrenbach (1995) provide detailed data on German mining activities including the number of employees in mining, covering the period until the 1970s. Information on quantities and market prices by commodity on an annual basis are available. Additional information was collected from Mitchell (2007). Data provided by Fischer (1989) and Fischer and Fehrenbach (1995) are also available by German state, which allows subtracting contemporary contributions of the mining sector of Alsace-Lorraine between 1871 and 1918. Moreover, the statistical offices of the German Empire and the Federal Republic of Germany provide information on the 1914 to 1923 as well as the post-1962 periods, respectively (Bundesamt, 2013; Germany. Statistisches Reichsamt., 1925). To assess the costs of depletion the number of employees in mining and their average wage were used. Data on the labour force in mining is provided by Fischer (1989), Fischer and Fehrenbach (1995), and the German Statistical Office (2013). Wages of mining workers are reported by Hoffmann et al. (1965), Kuczynski (1947), Mitchell (2007), and official contemporary statistics (Germany. Statistisches Reichsamt., 1925). Expenditure on schooling: Data on education expenditure is provided by Hoffmann et al. (1965) and Diebolt (1997, 2000). For the post-1990 period we use World Bank data on education expenditure. Missing values for the periods 1922-24 and 1938-48 have to be estimated. For the former period, we assume that expenditures between 1921 and 1925 developed gradually and apply linear interpolation. For the latter period we use Flora (1983, p. 585) who reports that the number of pupils and students in Germany dropped by 16.3 per cent between 1936 and 1950 – this occurred most likely due to population losses after WWII. The corresponding drop in education expenditure was 16.5 per cent. We assume that the 1939 expenditure level was maintained until 1945, when the number of students plummeted. Therefore, we assume that the expenditure level between 1946 and 1948 was equal to the 1949 figure. Carbon emissions were taken from Andres et al. (1999) and Boden et al. (1995). TFP: Data on labour hours worked and real GDP is taken from Greasley and Madsen (2006). Information on capital stock for the period 1850 through 2000 is provided by Metz (2005). Missing values during and after WWII have been estimated on the basis of Krengel (1958). Factor shares used were from Greasley and Madsen (2006), capital share is 0.60 and labour 0.40. A Kalman filter of the TFP growth rate was estimated. Discount rates were taken from Homer and Sylla (2005) and Deutsche Bundesbank (2013)[2].

Switzerland

GDP: Halbeisen et al (2012), Wirtschaftsgeschichte der Schweiz im 20. Jahrhundert. Basel: Schwabe; HSSO: Historische Statistik der Schweiz Online (Historical Statistics of Switzerland online), Kammerer Patrick et al. (Hg.), www.fsw.uzh.ch/histstat/main.php.; Capital: Halbeisen et al. (2012); BFS Online: Swiss Statistics, Swiss Federal Statistical Office (BFS), www.bfs.admin.ch/; Kehoe and Ruhl (2003); Goldsmith (1981); Siegenthaler and Ritzmann-Blickenstorfer (1996); Education expenditure: BFS Online: Swiss Statistics, Swiss Federal Statistical Office (BFS), www.bfs.admin.ch/; HSSO: Historische Statistik der Schweiz Online (Historical Statistics of Switzerland online), Kammerer Patrick et al. (Hg.), www.fsw.uzh.ch/histstat/main.php; Forest: HSSO: Historische Statistik der Schweiz Online (Historical Statistics of Switzerland online), Kammerer Patrick et al. (Hg.), www.fsw.uzh.ch/histstat/main.php; Siegenthaler and Ritzmann-Blickenstorfer (1996); BFS Online: Swiss Statistics, Swiss Federal Statistical Office (BFS), www.bfs.admin.ch/; LFI Online: National forest inventory Switzerland LFI, http://www.lfi.ch/resultate/suche.php; Rieger (2007); Costs of production: BAFU (2010). Biodiversität und Holznutzung – Synergien und Grenzen. Federal Office for the Environments Switzerland (BAFU), April 2010; BAFU (2011). Jahrbuch Wald und Holz - Annuaire La forêt et le bois – Federal Office for the Environments Switzerland (BAFU); Strawe (1994); HSSO: Historische Statistik der Schweiz Online (Historical Statistics of Switzerland online), Kammerer Patrick et al. (Hg.), www.fsw.uzh.ch/histstat/main.php.; Degen (2012); BFS Online: Swiss Statistics, Swiss Federal Statistical Office (BFS), www.bfs.admin.ch/; Studer (2008); Fossil fuel: Marek (2008); Marek (1994); (Gisler, 2011); Gebhardt (1957); Bellwald (2013); BFS Online: Swiss Statistics, Swiss Federal Statistical Office (BFS), www.bfs.admin.ch/ Iron ore: Fehlmann H. & Durrer R. (1932); HSSO: Historische Statistik der Schweiz Online (Historical Statistics of Switzerland online), Kammerer Patrick et al. (Hg.), www.fsw.uzh.ch/histstat/main.php.; IEA online: International Energy Agency (IEA), http://www.iea.org/countries/membercountries/switzerland/; BFS Online: Swiss Statistics, Swiss Federal Statistical Office (BFS), www.bfs.admin.ch/; Kündig and Leuenberger (1997); Bärtschi, 2011; Gesis online, Historische Statistiken, Historical statistics (Histat): http://www.gesis.org/histat/; Population: BFS Online: Swiss Statistics, Swiss Federal Statistical Office (BFS), www.bfs.admin.ch/; HSSO: Historische Statistik der Schweiz Online (Historical Statistics of Switzerland online), Kammerer Patrick et al. (Hg.), www.fsw.uzh.ch/histstat/main.php.; Discount rates: BFS Online: Swiss Statistics, Swiss Federal Statistical Office (BFS), www.bfs.admin.ch/; TFP: Halbeisen et al, (2012).

Latin America

6.1 Latin America

6.1.1 Argentina

GDP and GDP deflator: Argentina – From 1900-2000 the nominal GDP was derived from Della Paolera and Taylor (2003). GDP deflator is based on data from MoxLAD (2014) from 1900-1960 and on data from World Bank (2014b) for years thereafter.

6.1.2 Brazil

Brazil – Nominal GDP and GDP deflator were derived from the historical series from IBGE (2014).

6.1.3 Chile

Chile – From 1900-1940 the nominal GDP in USD was calculated using Hofman (2000). From 1940-1995 the nominal GDP was taken from Braun-Llona et al. (2000) and from 1995-2010 from Banco Central de Chile (2014). The GDP deflator was derived from World Bank (2014b) from 1960-2010. Braun-Llona et al. (2000) reports a real GDP series from 1900-1995 in prices from 1995.

6.1.4 Colombia

6.1.5 Mexico

6.1.6 Uruguay

Labat et al. (2019)

6.1.7 Venezuela

Colombia – The nominal GDP was taken from GRECO (1999b) from 1905-1997 and from 1998-2010 from World Bank (2014b). For the years before 1905 the GDP was calculated using the growth rate reported by Hofman (2000). From 1900-1960 the GDP deflator was derived by using the variations given by GRECO (1999b), after 1960 is it taken from World Bank (2014b). Mexico – From 1900-1970 the nominal GDP was taken from INEGI (2009), following years are derived from World Bank (2014b). The GDP deflator was calculated using the GDP deflator reported by MoxLAD (2014). Consumer price index and inflation: Argentina, Brazil, Mexico – data were taken from Clio infra (2014). Chile – 1900-1995 from Braun-Llona et al. (2000); from 1995 and thereafter from Clio infra (2014). Colombia – 1900-1905 from Braun-Llona et al. (2000) and from 1905 to 1996 data is from GRECO (1999b). For the last years it was taken from World Bank (2014b). Exchange rates and changes in local currency units (LCU): Argentina – data from Della Paolera and Taylor (2003). The exchange rate from Nuevos Pesos to USD from 1916 until 1999 was taken from Della Paolera and Taylor (2003) and for later years from Clio infra (2014). Brazil – Changes in LCU were derived from MoxLAD (2014); the exchange rate from LCU to USD from IBGE (2014). Chile – Changes in LCU are reported by MoxLAD (2014). From 1900-1995 the exchange rate to USD is reported by Braun-Llona et al. (2000), while later years were taken from Banco Central de Chile (2014). Colombia – exchange rate from Pesos to USD was taken from GRECO (1999b) from 1905-1997; for the following years it is from CEPAL (2014). Mexico – Changes in LCU were taken from MoxLAD (2014); the exchange rate to USD was derived from INEGI (2009) until 2009, while later years are from CEPAL (2014). Investment and gross fixed capital formation (GFCF) – All countries – The series for GFCF after 1950 was taken from CEPAL (2009) and CEPAL (2014). These data was converted to real prices of 2010 and calculated for the years from 1900-1950 using the index reported by Tafunell (2011). Tafunell (2013) explains the method to build the GFCF data on non-residential construction and machinery and equipment. The article by Tafunell and Ducoing (2015) is an extension of the latter. Consumption of fixed capital – All countries – World Bank (2014b) reports information starting in 1970. For previous years data was estimated using the methodology reported by the World Bank in Bolt et al. (2002). Overseas investment – All countries – From 1900-1949 data is based on Taylor (1998). Argentina, Colombia, Mexico: From 1950-1969 data was taken from CEPAL (2009) and for later years from World Bank (2014b). Brazil, Chile: Data is taken from CEPAL (2014) from 1950-1974 and later from World Bank (2014b). Natural resources: Forestry – All countries – Annual change of forest area for the period of 1900-1985 was taken from Houghton et al. (1991). Forest area after 1990 was taken from the World Bank (2014b). Minerals & Energy - Argentina – Gold, silver: 1921-1944: Imperial Mineral Resources Bureau (various years); 1949-1954: Colonial Geological Surveys (various years); 1955-1969: Institute of Geological Sciences (various years-a); 1970-1980: Institute of Geological Sciences (various years-b); 1981-1991: British Geological Survey (various years); 1992-2010: British Geological Survey (2014); Rothwell (1898) reports data for 1895-1897. Copper: 1913-1944: Imperial Mineral Resources Bureau (various years); 1960-1969: Institute of Geological Sciences (various years-a); 1970-1973: Institute of Geological Sciences (various years-b); 1974-2008: CEPAL (2014); 2009-2010: British Geological Survey (2014). Missing years were linearly interpolated. Coal: 1939-2002: Mitchell (1998); 2003-2008: CEPAL (2014); 2009-2010 were assumed to be constant as 2008. Iron ore: 1937-1989 Mitchell (1998), 1990-2010 World Steel Association (2014). Natural gas: 1929-1966: Mitchell (1998); 1970-1980: Institute of Geological Sciences (various years-b); 1981-1991: British Geological Survey (various years); 1992-2010: British Geological Survey (2014). Crude petroleum: 1915-2002 Mitchell (1998); 2003-2010: British

Geological Survey (2014). Lead: 1920-2000: Mitchell (1998); 2001-2010: British Geological Survey (2014). Tin: 1923-1944: Imperial Mineral Resources Bureau (various years); 1944-54: Colonial Geological Surveys (various years); 1955-1970: Institute of Geological Sciences (various years-a); 1974-1995 CEPAL (2014), from 1996-2010 production was assumed to be constant as value of 1995. Zinc: 1939-1944: Imperial Mineral Resources Bureau (various years), 1945-1955: Institute of Geological Sciences (various years-a); 1956-2003: Mitchell (1998); 2004-2008: CEPAL (2014); 2009-2010: British Geological Survey (2014). Brazil – Gold: 1913-1944: Imperial Mineral Resources Bureau (various years), 1949-1954: Colonial Geological Surveys (various years); 1955-1969: Institute of Geological Sciences (various years-a); 1970-80: Institute of Geological Sciences (various years-b); 1981-91: British Geological Survey (various years); 1992-2010: British Geological Survey (2014); Rothwell (1898) reports data for 1895-1897. Silver: 1913-44: Imperial Mineral Resources Bureau (various years), 1949-54: Colonial Geological Surveys (various years); 1955-1969: Institute of Geological Sciences (various years-a); 1970-80: Institute of Geological Sciences (various years-b); 1981-91: British Geological Survey (various years); 1992-2010: British Geological Survey (2014). Copper: 1955-1960: Institute of Geological Sciences (various years-a); 1965: Instituto Brasileiro de Mineração (2013), 1974-2008 CEPAL (2014); 2009-2010: British Geological Survey (2014). Coal: 1913-2002: Mitchell (1998); 2003-2008: CEPAL (2014); 2009-2010 was assumed to be constant as value in 2008. Iron ore: 1923-1935: Imperial Mineral Resources Bureau (various years); 1936-92: Mitchell (1998), 1993-2008: CEPAL (2014); 2009-2010: British Geological Survey (2014). Natural gas: 1942-1966: Mitchell (1998), 1972-1980: Institute of Geological Sciences (various years-b); 1981-1991: British Geological Survey (various years); 1992-2010: British Geological Survey (2014). Crude petroleum: 1942-2002: Mitchell (1998); 2003-2010: British Geological Survey (2014). Lead: 1921-1944: Imperial Mineral Resources Bureau (various years); 1945-2003: Mitchell (1998); 2004-2010: British Geological Survey (2014). Tin: 1943-2002: Mitchell (1998); 2003-2008: CEPAL (2014); 2009-2010: British Geological Survey (2014). Zinc: 1965-2003: Mitchell (1998); 2003-2008: CEPAL (2014); 2009-2010: British Geological Survey (2014). Aluminium/ bauxite: 1953-1991: Mitchell (1998); 1992-2010: British Geological Survey (2014). Chile – Gold, silver: 1900-1995: Braun-Llona et al. (2000), 1996-2010: British Geological Survey (2014). Copper: 1900-1995: Braun-Llona et al. (2000); 1996-2008: CEPAL (2014); 2009-2010: British Geological Survey (2014). Coal: 1900-1990: Braun-Llona et al. (2000); 1991-2008: CEPAL (2014); 2009-2010 the production volume of 2008 was assumed. Iron ore: 1911-1998: Mitchell (1998); 1990-2007: CEPAL (2014); 2009-2010: British Geological Survey (2014). Natural gas: 1952-1966: Mitchell (1998); 1970-1980: Institute of Geological Sciences (various years-b); 1981-1991: British Geological Survey (various years); 1992-2010: British Geological Survey (2014). Crude petroleum: 1949-2002: Mitchell (1998); 2003-2010: British Geological Survey (2014). Lead: 1920-1944: Imperial Mineral Resources Bureau (various years), 1945-1954: Colonial Geological Surveys (various years); 1955-1969: Institute of Geological Sciences (various years-a); 1970-1980: Institute of Geological Sciences (various years-b); 1981-1991: British Geological Survey (various years); 1992-2010: British Geological Survey (2014). Zinc: 1926-33: Imperial Mineral Resources Bureau (various years); 1953-54: Colonial Geological Surveys (various years); 1955-1970: Institute of Geological Sciences (various years-a) missing years were assumed to be zero as production is already very low in the years before; 1974-2008: CEPAL (2014); 2009-2010: British Geological Survey (2014). Colombia - Gold, silver: 1913-1929: Imperial Mineral Resources Bureau (various years). 1931-2010: UMPME (2014). Copper: 1951-2010: UMPME (2014). Coal: 1926-32: Imperial Mineral Resources Bureau (various years); 1933-1949: Mitchell (1998); 1950-2010: Mineral Agency of Colombia. Iron ore: 1960-1998: Mitchell (1998); 1999-2010: British Geological Survey (2014). Natural gas: 1952-1966: Mitchell (1998); 1970-1980: Institute of Geological Sciences (various years-b); 1981-1991: British Geological Survey (various years): 1992-2010: British Geological Survey (2014). Crude petroleum: 1922-2005: Mitchell (1998); 2003-2010: British Geological Survey (2014). Lead: 1960-1985: Mitchell (1998); 1990-2010: Mosquera and Bautista (2005). Zinc: 1960-1970: Institute of Geological Sciences (various years-a). Mexico - Gold, silver: 1900-2008: INEGI (2009); 2009-2010: British Geological Survey (2014). Copper: 1900-1975: INEGI (2009); 1976-2003: Mitchell (1998); 2004-2007: CEPAL (2014); 2008-2010: British Geological Survey (2014). Coal: 1900-2008: INEGI (2009). Iron ore: 1900-2008: INEGI (2009); 2009-2010: British Geological Survey (2014). Natural gas: 1932-1966: Mitchell (1998); 1970-1980: Institute of Geological Sciences (various years-b); 1981-1991: British Geological Survey (various years); 1992-2010: British Geological Survey (2014). Crude petroleum: 1901-2007: INEGI (2009). Lead: 1900-2008: INEGI (2009); 2009-2010: British Geological Survey (2014). Tin: 1903-2008: INEGI (2009). Zinc: 1900-2008: INEGI (2009); 2009-2010: British Geological Survey (2014). Resource prices: Coal: 1900-1971: U.S. Bureau of Mines (2014); 1972-2010: U. S. Energy Information Administration (2012). Crude petroleum, lead, copper, silver, tin, zinc: 1900-2010: The price index was taken from MoxLAD (2014). Natural gas: 1922-2010: U.S. Energy Information Administration (2014). Iron ore: 1900-2010: U.S. Geological Survey (2014). Gold: 1908-2000: GRECO (1999a); 2001-2010: World Bank (2014a). Bauxite: 1900-2010: U.S. Geological Survey (2014). Labor costs were calculated by multiplying the economically active populations (EAP) in the extractive industry with the average real wage. Argentina - 1914-1990: EAP of the extractive industry was taken from Mitchell (1998), who reports data for the years 1914, 1947, 1960, 1970 and 1980. For 1980 and 1985 data from CEPAL (2014) and from 1990-2010 data from World Bank (2014b) was available for the total workforce. Brazil - From IBGE (1990) information about the EAP in extractive industry from 1900-1989 are available. From 1990-2010 data from the World Bank (2014b) about the total workforce was available. From 1990 to 1995 the percentage of occupied population in the extractive industry from the whole labor force was calculated. Chile - Braun-Llona et al. (2000) gives the number of people working in mining as well as percentages of people working in mining from the whole labor force from 1900-1995. From 1996 the total EAP was available from World Bank (2014b). Colombia - Mitchell (1998) reports the EAP in the extractive sector for 1938, 1951, 1964, 1973, 1992 and 2004. Data about the general workforce is available from GRECO (1999b) between 1925 and 1996 as well as between 1997 and 2010 from World Bank (2014b). Mexico - INEGI (2009) reports the EAP in the extractive and petroleum industry from 1900-1997 and from 1998-2004 the EAP in the extractive and petroleum sector. The discount rate for calculating the PV of future changes in real wages is based on each country's geometrical average of real GDP growth rate. Population: Argentina – From 1900-1996 the population was taken from Braun-Llona et al. (2000) and thereafter from INDEC (2014). Brazil - The whole series was taken from IBGE (2014). Chile – From 1900-1995 data was derived from Braun-Llona et al. (2000) and for years after 1996 from Banco Central de Chile (2014). Colombia – From 1905-1997 data was derived from GRECO (1999b), the following years were from DANE (2014). The first five years were calculated using the average growth rate between 1905 and 1915. Mexico – The whole series until 1995 was taken from Braun-Llona et al. (2000), the following years from World Bank (2014b). Education expenditure: Argentina – World Bank (2014b) and MoxLAD (2014). Brazil – From 1930-2004 data was calculated with information on education expenditure which is given as a percentage of GDP by Rodrigues M. (2007). From 2004-2010 data is reported by World Bank (2014b). Chile - Braun-Llona et al. (2000) report data for the period between 1900 to 1996. The data series was completed with World Bank (2014b). Colombia – Data from Helg (2001), DANE (1985), World Bank (2014b) and MoxLAD (2014). Mexico – From 1900-1966 data is derived from INEGI (2009) and from 1997-2014 from INEGI (2014). Carbon emissions: All countries – Data on emissions are reported by Boden et al. (2014). The prices for CO2 were calculated using the methodology presented by Tol (2012) who estimated a CO2 price of 29 USD per ton in 2015. The prices for other years are calculated by discounting it with a rate of 1.99 %. TFP: LA ASTORGA, P., BERGÉS, A. R., & FITZGERALD, V. (2011). PRODUCTIVITY GROWTH IN LATIN AMERICA OVER THE LONG RUN. Review of Income and Wealth, 57(2), 203–223. http://doi.org/10.1111/j.1475-4991.2011.00447.x Argentina – From 1900-1993 TFP growth is reported by Elias (1996) and from 1993-2010 from data estimated by Feenstra et al. (2013). Brazil, Chile – From 1900-1950 data was derived from Elias (1996). These growth rates were assumed to be constant for every decade. From 1950-2010 growth was calculated from the series estimated by Feenstra et al. (2013). Colombia – From 1900-1950 growth rates are reported by Astorga et al. (2003); thereafter we used a series provided by Feenstra et al. (2013). Mexico – From 1900-1950 growth rates are derived from Baier et al. (2006). From 1950-2010 the growth was calculated from the series estimated by Feenstra et al. (2013). The value of technology in the economy was calculated using the methodology in Pezzey et al. (2006).