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Accounting for Sustainable Development over the Long-Run: Lessons from Germany

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JEL codes: E01, E21, N10, O11, 044, Q01

Accounting for sustainable development over the long-run: lessons from Germany.[♦]

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Abstract:

For many years, the World Bank has reported estimates of the degree of sustainability of the world's economies using a measure of adjusted net savings. We construct long-run sustainability indicators for Germany over the period 1850-2000 to test the relationship between these net savings-based indicators and a number of measures of well-being over the long-run. These are the present value of future changes in consumption and changes in average height and infant mortality rates. We find that German sustainability indicators are positive for the most part, although they are negative during and after the two World Wars and also the Great Depression. However, we do not observe similar trends in the path of future consumption. Overall, we find that Genuine Savings is positively related to the present value of changes in future consumption, with some evidence of a cointegrating relationship when the measure of changes in assets is made more comprehensive. Our main contribution is to demonstrate the importance of broader measures of capital, including measures of technological progress; and the limits of conventional measures of investment to understand why future German consumption did not collapse.

Keywords: Sustainability, economic development, Genuine Savings, Adjusted Net Savings, investment, consumption, well-being, economic history.

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1. Introduction

Genuine Savings (GS), or Adjusted Net Savings, is an indicator of sustainability based on the concept of wealth accounting (Hamilton & Hepburn 2014). Ideally, GS measures how a country's total capital stock (physical, natural, social or institutional & human) changes year-on-year. Since the mid-1990s the World Bank has published estimates of GS (e.g. World Bank (1995, 1997)). Hamilton & Clemens (1999) and World Bank (2006, p. 36) illustrate the nature of these estimates for almost all countries in the world and show how a negative GS indicator can be interpreted as a signal of unsustainable development.[4] Current World Bank data to support the calculation of GS at the country level stretches back to the 1970s, and provides empirical evidence of the level of sustainable/unsustainable economic development throughout the world: the recent 2012 global average GS rate was positive (9.24 per cent of Gross National Income).

But what can the historical record tell us about the sustainable development of countries? Recent work has constructed long-run GS estimates for Britain, and shows that throughout its history Britain's GS rates have been positive on the whole (Greasley et al 2014). This paper also approaches the concept of GS over the long run, and looks to the checkered history of Germany to construct and test measures of GS over the period 1850 to 2000. Germany underwent unification and was a belligerent in two World Wars and also experienced the Great Depression during this time period. German GS rates averaged 11.16 per cent of GDP over the period of this study, with a coefficient of variation of 0.84. We find consistently positive GS rates apart from the World Wars and the Great Depression.

The primary purpose of this paper is to test whether one of the main implications of the theory of sustainable development is consistent with empirical facts for Germany over the

[4] The World Bank has annually updated estimates and the most recent estimates covered 129 and 110 countries in 2011 and 2012: Data taken from http://data.worldbank.org/topic/environment [accessed 4 November 2014]

long run. Therefore, this paper investigates the relationship between GS and well-being in Germany over the period 1850 to 2009. In so doing, it examines the long-run relationship between changes in Germany's comprehensive wealth and future well-being. Previous empirical tests of the relationship between GS and future well-being have mainly focussed on shorter historical periods, for example from 1970 to 2000 (Ferreira, Hamilton and Vincent, 2008; although see Greasley et al (2014) for an exception). By adopting a longer term historical framework, we test for long-run relationships between indicators of sustainability and future consumption. As sustainability is essentially a long-run concept, the advantage of historical analysis compared to shorter-run contemporary focused analysis is that it can analyse sustainability issues over longer horizons than can be tested with data covering only recent decades. We add to Greasley et al by comparing the relationships of alternative measures of well-being with changes in total capital: namely the present value of future changes in consumption per capita and non-monetary measures of average height and infant mortality rates. Germany also turns out to provide an important contrast with the picture for Britain, especially in terms of an apparent mis-match between GS and future consumption in the post-war periods. We investigate this in detail.

Indeed, using German economic development as a case study offers several advantages. During its rapid phase of industrial industrialisation in the 20th century, Germany was more a follower than a leader in terms of economic progress. Its success was partly based on its role as a latecomer to the first Industrial Revolution, and an imitator of previous development successes (such as the UK). It was also a pioneer in the "second industrial revolution" in the field of chemistry and electricity, but its success was also based on exploitation of national resources and the rising emissions of pollutants in the atmosphere. The lessons of German development are perhaps more relevant for modern developing countries than Britain, as Germany was a late developer in the nineteenth century. In 1850

Germany's GDP per capita was $GK 1428, it not only lagged behind contemporary leaders such as the UK ($GK 2330) and the USA ($GK1806), but it was considerably less well-off than developing countries in more recent years. For example, a number of world regions former USSR (GK$7877), Latin America ($GK 7027), East Asia ($GK 2267), West Asia ($GK 6931) and Africa ($1924) had higher GDP per capita levels in 2008 than Germany in 1850 (Bolt & Van Zanden 2013). This similarity to modern-day emerging economies makes Germany a case study that can provide valuable insight into the impact of (un)sustainability of current economic development. Moreover, Germany's experiences during and after the First and Second World Wars can be considered massive natural experiments. We find that the largest year-on-year falls in consumption per capita occurred during and immediately after the First and Second World Wars, however, the German economy was resilient enough to overcome these consumption shocks. This historical scenario may serve as a basis to test whether the theoretical model can cope with economic shocks such as the war-related destruction of physical capital and dismantlement as well as the destruction of human and social capital, or whether its implications only hold for peacetime economic scenarios.

This paper develops as follows. First, we outline the underlying theoretical framework that forms the basis of our empirical strategy, and then we introduce the data used in this paper. We then discuss empirical findings using conventional measures of well-being as well as alternative measures, along with a range of robustness checks. Finally we conclude with some discussions and suggestions for future research.

2. A framework for empirical tests of the relationship between genuine savings and future well-being

Sustainable development as a concept is a broad church with growing literatures in several academic disciplines (e.g. earth sciences, ecology, economics, and sociology: see

Rogers et al 2008). Although there are non-economic definitions of sustainability, the focus here is on the economic definition of sustainable development.[5]

Economists' definitions of sustainable development can be categorised into those based on outcomes, and those based on capabilities (Hanley et al., 2006). Outcome-based definitions focus on non-declining utility, well-being or consumption per capita over time, or define sustainable development as a pattern whereby utility in any time period does not exceed a maximum, sustainable level determined by technology and resource endowments (Arrow et al., 2012; Hamilton and Withagen, 2007; Pezzey, 2004). In contrast, capabilities-based definitions involve some idea of non-declining capital over time. For instance, Neumayer (2010) defines sustainable development as '*a pattern over time where… the value of an economy's total stock of capital is maintained'*. By total capital stock, we mean all assets which are important for generating flows of well-being over time, namely produced capital (e.g. roads, machines), natural capital (e.g. coal reserves, forests), human capital (skills, capabilities) and social or institutional capital. This capital-based definition presumes that the aggregate production function of the economy is characterised by a sufficient degree of substitutability between these different elements of a nation's total assets such that no constraint needs to be placed on the time path of any particular element of this overall capital stock. Moreover, it is assumed that all assets can be measured in monetary terms, using appropriate shadow prices. One implication is that a country can deplete its natural capital whilst remaining on a sustainable path so long as enough of the rents from natural capital

[5] Within economics there are two schools of thought. Those who adhere to the weak sustainability paradigm which assumes substitutability of capital and those who adhere to the strong sustainability paradigm, who believe that there is a limit to substitutability and that there are critical levels of natural capital. We do not address this debate here, but start with an assumption of weak sustainability, since this is what Genuine Savings is based on.

extraction are re-invested in other forms of capital, when valued at correct shadow prices – the Hartwick Rule (Hartwick, 1977).[6]

Given such an economy, a macro level test of sustainable development would thus be to examine whether, year-on-year, an economy's per capita total capital stock is falling, rising, or remaining constant in value terms. Such "comprehensive wealth accounts" are increasingly prominent in inter-governmental initiatives over sustainable development (e.g. UNEP, 2012). Beginning with Pearce and Atkinson (1993), the Genuine Savings[7] indictor has emerged as one such measure of changes in a nation's overall capital stock. Conceptually, Genuine Savings (GS) adds up the value of year-on-year changes in each individual element of the capital stock of a country, valuing these changes using shadow prices which reflect the marginal value product of each stock in terms of its contribution to welfare, which in turn is defined as the present value of aggregated utility over infinite time. Empirically, data on actual market prices and costs are used: these may be quite different to the equivalent shadow prices. Moreover, prices for some environmental assets do not exist due to missing markets.

The intuition of Pearce and Atkinson (1993) was that countries with positive levels of GS would satisfy a requirement of weak sustainability, since by implication their total capital stocks would not be declining in value. Concomitantly, countries with negative GS values would be experiencing un-sustainable development. A formal proof of a theoretical link between GS and future well-being is provided by Hamilton and Withagen (2007), who showed that, under certain conditions,[8] a country with a positive GS would experience increasing consumption into the future. In contrast, Pezzey (2004) argues that GS is only a one-sided indicator which can only prove un-sustainability, due to the failure to use what

[6] The Hartwick Rule shows conditions under which constant consumption is possible over time for a resource-dependent economy with Cobb-Douglas technology.
[7] Also referred to as Adjusted Net Savings or Comprehensive Investment.
[8] A present-value maximising economy with no externalities, and where GS is growing over time at a rate less than the real interest rate.

have been termed "sustainability prices" which include sustainability constraints to value changes in capital stocks. Moreover, he argues that there is no theory linking negative GS with un-sustainability away from an optimal (PV-maximising) path. A somewhat different perspective was offered by Dasgupta and Maler (2000), who showed that a measure of change in wealth stocks year-on-year can be used as an indicator of sustainable increases in well-being in non-optimising economies or imperfectly competitive economies (Hanley et al, 2014).

While the theoretical underpinnings of the GS indicator of sustainability are reasonably well-established, there are, however, limited tests of the predictive power of GS. This paper follows the empirical strategy of World Bank (2006),[9] Ferreira et al. (2008), and Greasley et al. (2014), who look at the relationship between the present value of future changes in consumption and a set of comprehensive sustainability indicators. Ferreira et al. (2008) use panel data for 64 developing countries during the period 1970 through 1982 to test the relationship between GS and the present value of changes in future consumption. They base this on their representation of the long-run equilibrium relationship between GS and future well-being derived in their paper:

$$PVC_t = \beta_0 + \beta_1 GS_t + \varepsilon \qquad (1)$$

where PVC_t is the present value of changes in future consumption over some defined time period as evaluated at period t. The strongest test of the theory is:

H1: $\beta_0 = 0$ and $\beta_1 = 1$;

The key results that emerge from Ferreira et al. (2008) are that their strong hypothesis is rejected for all models. However, they report significant correlation between GS and the present value of future changes in consumption, when GS or population-adjusted GS is used as the measure of net investment. In a somewhat similar vein to Feirrera et al (2008), World

[9] These tests draw on Hamilton (2005).

Bank (2006) tests GS using a series of yearly cross-sections from 1977-1980. World Bank (2006) finds positive relationships between GS and present value of changes in future consumption, with β_1 coefficients ranging between 0.78 and 1.28.

Greasley et al. (2013; 2012; 2014) investigate the long-run relationship between real wages and comprehensive investment in Britain and the U.S, using the same hypothesis testing structure as Ferreira et al. (2008). For the UK, data is analysed over the period 1760-2000, and for the USA from 1869-2000. They found that the choice of time horizon and discount rate respectively, had the greatest effect on the estimated parameters than the alternative net savings measures used. Overall, they found that the inclusion of measures of technology, which they proxied using the present value of changes in Total Factor Productivity (TFP) substantially improved the power of prediction of the estimated parameters giving β_1 coefficients close to 1. Once technological progress was included within the measure of GS, then a cointegrating relationship was detected between GS and consumption growth.

In this paper, we extend Greasley et al's (2012, 2013, 2014) results by (i) considering a country with a very different economic history to the US or UK; (ii) considering the effects of war and territorial change on the relationship between GS and well-being and (iii) including alternative indicators of well-being (rather than consumption) based on anthropometrics (Baten and Blum, 2012).

3. German GS estimates, 1850-2000

We have largely followed the World Bank (2006, 2011) methodology for calculating GS to produce a range of increasingly-comprehensive measures of year-on-year changes in total capital for Germany over time. We construct the following indicators:

1. Net investment = net fixed produced capital formation and overseas investment

2. Green investment = indicator (1) +Δ natural resource rents
3. Genuine Savings (GS) = indicator (2) + education expenditure
4. GS carbon = indicator (3) + carbon emissions
5. GreenTFP = indicator (2) + the present value of TFP growth
6. GSTFP = indicator (3) + the present value of TFP growth

The subsequent section outlines the historical trends in these data and a more comprehensive description of data and sources is provided in the accompanying data appendix.

3.1 Changes in produced and net overseas capital: net investment.

The net investment series we use comprises domestic net investment in produced capital (e.g. factories, machine tools, and transport links) and changes in foreign net capital stock, of which domestic investment is the major component. [10] Overall net investment varied around a 10 per cent of GDP during the mid-19th century. During the heyday of the German economy in the late 19th and early 20th century, net investment increased to approximately 15 per cent of GDP. Massive shocks occurred during the First World War, the inter-war years, and especially towards the end of the Second World War and the immediate post-war years when war destruction and dismantlement resulted in highly negative net saving rates. German net investment was generally positive during the Nazi era, resulting in capital accumulation, especially in the heavy industries (Kirner, 1968; Vonyó, 2012). During the years of the "economic miracle", net savings rate were on an all-time high, ranging between 15 per cent and 20 per cent. Until the mid-1970s net savings rates subsequently declined to a level under 10 per cent and remained there for most of the period between 1975 and 2000 (Figure 1).

[10] Information on net investment are taken from Hoffmann, W.G., Grumbach, F., Hesse, H., 1965. Das Wachstum der deutschen Wirtschaft seit der Mitte des 19. Jahrhunderts. Springer-Verlag, Berlin, Heidelberg, New York., which still serves as the main source for German historical national account series. See for example Metz (2005), who uses Hoffmann et al.'s (1965) series for estimating German capital stocks between 1850 and 2000. A wide array of German historical national account statistics using Hoffmann et al.'s figures can be downloaded under www.gesis.org/histat.

3.2 Natural capital

Natural capital consists of all "gifts of nature", including renewable and non-renewable resources, agricultural land, ecosystems and biodiversity (Barbier, 2011). Unfortunately, it was only possible to include a sub-set of these assets due to missing markets. Changes in the natural capital stock are calculated from data on physical changes in certain stocks (e.g. due to depletion, for non-renewables) and the per-unit rental values of these changes. Renewable sources include forestry and coastal fisheries. In terms of forestry, the only noteworthy changes to the German forest stock seem to occur due to changes in territory. Given the nature and size of these changes, we have not included changes in forestry stock. In the non-renewable sector, the most important commodities for Germany are brown and hard coal. Data on natural gas and crude oil depletion, iron ore, copper ore, zinc ore, lead ore, silver ore, tin ore, and nickel ore extraction are also included, but contribute only small shares to the overall figure on resource depletion. Costs of production have been subtracted from gross revenues using wages and employment figures in order to estimate the economic rent per unit of resource extracted. In Figure 2 the net-contribution (gross revenues minus average extraction costs) of non-renewable resource depletion is shown.[11]

3.3 Changes in the stock of human capital

The stock of human capital is an important component of total wealth (World Bank 2011). There are a number of ways of calculating stocks of human capital and therefore deriving changes in the stock. World Bank (2006, 2011) calculates human capital as a residual from total wealth, whilst Arrow et al (2013) calculate human capital using Mincer equations, elsewhere McLaughlin et al (2014) calculate stocks of human capital using the discounted

[11] Figure 2 illustrates this as a negative figure as we subtract it from net investment. See schema in section 3.

lifetimes earning. However, instead of estimating stocks of human capital here we follow Hamilton and Clemens (1999, p.334, 336) who argue that investment in human capital can be proxied using education spending.[12] Figure 3 indicates that schooling expenditure in Germany, including investment in primary, secondary, and tertiary education, generally increased from under 1 per cent of GDP in the mid-19th century to 6.2 per cent in 1974. In the nineteenth century Prussia was in fact a leader in the provision of publicly funded education (Lindert, 2004). Significant slumps occurred during the 1920s, the Second World War and the post-war years. Slumps during the 1920s and the war years are the result of disproportionate inflation of GDP relative to absolute education expenditure and a disproportionate economic upswing, respectively. Low human capital investment rate in the late 1940s are the result of generally low education expenditures combined with economic recovery. In terms of capturing information on public expenditure on schooling, we believe that our data series reflects this better than data provided by the World Bank database as this assumes education expenditure to be at a constant 4.3 per cent of GDP, whereas we utilise more accurate estimates provided by Diebolt (1997, 2000).

3.4. Carbon costs caused by pollution

In a further step, environmental costs due to pollution are considered, based on the idea that emissions of greenhouse gases deplete the global assimilative capacity for such emissions, and thus constitute a negative investment flow which should be priced according to estimates of marginal damage costs per tonne of emission (e.g. Pezzey and Burke 2014, Kunnas et al 2014). Over most of the period between 1850 and 2000, trends in German CO2 emissions correspond with overall economic activity, with increases before the end of the Second World

[12] This method has limitations as it assumes that schooling equates to human capital development and it excludes on the job training, apprenticeships and other informal forms of human capital development

War, brief interruptions in the 1920s and 1930s, a deep slump in the mid- and late-1940s, followed by a steep increase until the mid-1970s when absolute CO2 emissions started to decline. We use prices from Tol (2012) and discount the 2000 price, DM 37.96, in accordance with the growth rate of future prices (e.g. 1.99 per cent per annum). Expressed as a percentage of GDP, the value of carbon yields a small negative cost. Given the low value of carbon emissions relative to GDP, we do not anticipate that the inclusion of carbon in GS will affect our results dramatically.[13]

3.5 Changes in the value of exogenous technological progress (TFP)

We have incorporated the effects of exogenous technological progress in our measure of GS by including the present value of TFP growth. Weitzman (1997) suggested that such a technological change premium could be as high as 40 per cent of Net National Product, and that omitting a technological progress measure would mis-state the degree of sustainability of an economy. We have estimated trend TFP growth using sources outlined in the appendix, and use this to simulate the present value of the change in GDP over the coming 20 year period in any accounting period to proxy the "value of time" or value of exogenous technological progress following Pezzey et al. (2006). In line with Weitzman (1997), we find that the present value of TFP averages 44.60 percent of GDP over the period 1851-2000.

TFP is a well-accepted proxy for technological progress in economic history, but also encompasses other factors unrecorded in the production process such as institutions and social capital. Institutional change is an attractive explanation for the odd combination of highly negative investment between 1944 and 1948 and high changes in future consumption, since the Nazi regime was replaced by a more democratic political process after 1945 which paved the foundations for a functioning market economy, and which stabilized the economy

[13] See Kunnas et al (2014) for a more comprehensive treatment of the issue of carbon pricing.

at large. Social capital is also an important factor which is unaccounted for by conventional metrics. In addition, the effects of the presence of U.S. and Allied forces in creating a more harmonious geo-political environment cannot be underestimated – for example the European Coal & Steel Community and the European Economic Area arose out of it.

3.6 Consumption as a welfare indicator

Private consumption per capita over the period 1850 to 2009 is used to measure changes in future well-being.[14] Limited as it may be, this reflects the economic outcomes for a population in constant monetary units. To implement the hypotheses tests set out earlier derived from Ferreira et al (2008), the present value of the change in future consumption was calculated over four time horizons (20, 30, 50, and 100 years ahead) using a 1.95 per cent discount rate (the average real interest rate in Germany from 1850-2010) and also using a 3.0 per cent discount rate (the average rate of real GDP growth over the time period). Figure 5 illustrates the present value of changes in consumption per capita over five different time horizons are presented.

An interesting facet evident in the underlying consumption data is that from 1850-2009 there is a year-on-year decrease in consumption in a total of 55 years, 36.66 percent of the data. However, when we calculate the present value of changes in consumption over the various time horizons (20, 30, 50, and 100 years), we get much a lower number of negative values and these decrease from 22.86 percent in the 20 year horizons to 0 for the latter two time horizons. Given Germany's eventful history – two World Wars and the Great Depression caused significant scars both from an social and economic point of view – a key question is why these drastic events did not result in a substantial decrease in future

[14] This ignores the value of changes in the value of leisure time over the period, and other elements of full consumption.

consumption as theory suggests; in fact, we only find 1 negative value over the 20 year horizon (1914) and 2 negative values over the 30 year horizon (1914 and 1915) and none for 50 or 100 horizons. Thus, despite collapses in our conventional measures of GS (1-4 above) in 1919, 1931-32 and 1945-1948, and although there are some year-on-year falls in consumption, we do not find similar drops in the present value of future changes in consumption. Why did German consumption not collapse and what factors other than conventional investment measures account for this? We believe that this may be explained by considering broader measures of capital which take into account changes in social and institutional capital.

4. Testing the empirical relationship between Genuine Savings and future well-being

Figures 6a-c show the results of our calculations of GS for Germany and table 1 outlines decadal averages of all components outlined in section 3. Following Ferreira et al. (2008), we have tested the relationship between these increasingly comprehensive indicators of wealth changes and the present value of changes in future consumption. As noted above, this is based on a theoretical relationship between changes in capital in the accounting period and future changes in well-being. In the strong version of the theory, we should find $\beta_1 = 1$ and $\beta_0 = 0$, since in the absence of positive net investment the future change in consumption is expected to be zero. A weaker test of the theory is to examine whether $\beta_1 > 0$.

Before testing these hypotheses empirically, an issue specific to the case of Germany needs to be addressed. The theoretical models underlying GS, such as described in Hamilton and Withagen (2007), do not take into account shocks such as war-related destruction and dismantlement in Germany during and after WWII. Figure 7 illustrates the relationship between GS and present value of future changes in private consumption over a 50 year time horizon. A series of extreme values, referring to the years between 1944 through 1948, are located in the upper left of the scatterplot to illustrate this effect. Highly negative net investment rates go along with fairly high discounted differences in future consumption. Negative investment rates can be explained by capital being destroyed and damaged due to the wars, whilst positive differences in future consumption are mainly driven by a catch-up growth and consumption in the post-war era. If the Ferreira et al (2008) empirical strategy was applied to the complete dataset, the resulting estimated relationship is indicated by the dotted line. In this case, the existence of a small number of outliers reduces the value of the coefficient, systematically underestimating the empirical relationship between investment and discounted future consumption growth. If the war and post-war period are excluded, empirical tests reflect the relationship between GS and utility more accurately (solid line).[15]

4.1 Results

The intuition gained from figure 7 suggests that estimation based on the entire data set would be distorted since we are not able to explain the residuals of four outliers with the conventional GS framework. On account of this we do not consider observations referring to the period 1944-48 in the first set of empirical tests carried out below. Therefore, the benchmark results (table 2) exclude this period, but preserve other properties of the analysis.

Corresponding numerical results over five different time horizons are shown in table 2. Here β_0, β_1, the results of a series of Augmented Dickey-Fuller (ADF) tests, and several F-tests are shown. ADF tests aim at testing for a unit root in the residuals of a regression of the consumption variable and the investment variable. We use this test to investigate whether the

[15] We are aware of the standard econometric techniques that are normally applied to address time series with structural breaks (see for example Perron (1989) and Ben-David (1995)). However, for the sake of the argument made in this paper with respect to Germany's post-war catch-up growth, we would like to maintain this somewhat incomplete analysis as a baseline for test performed below. There, we will argue that the detrimental effects of the Second World War were compensated by technological change and social institutions.

consumption and comprehensive investment series are cointegrated in order to assess a potential long-term relationship of these indicators. F-tests are applied to test the hypotheses that $\beta_1 = 1$, and that $\beta_0 = 0$ and $\beta_1 = 1$ jointly. In our benchmark results our preferred discount rate is 1.95 per cent, which is based on real returns to German government bonds over the time period.

We apply a set of investment metrics over 20, 30, 50 and 100 year time horizons for the present value of future changes in consumption using a 1.95 per cent discount rate. In general, results indicate the existence of a positive relationship ($\beta_1 > 0$) between current investment and future well-being measured as private consumption. However, depending on the time horizon and investment indicator, the coefficient indicating the magnitude of this relationship varies considerably. The majority of tests indicate that $\beta_1 > 1$ and these coefficients tend to be larger for longer time spans. We also test the hypothesis that $\beta_1 > 0$ and $\rightarrow 1$ as the investment metric includes more types of capital. We find that this is the case for all time horizons when we consider resource extraction, education expenditure, and costs of pollution as parts of net investment in comprehensive wealth. Table 3 illustrates the effect of including the war years, the results also indicate a positive relationship between current investment and future well-being ($\beta_1 > 0$), however they are considerably lower over 20 and 30 year time horizons and over 50 year horizons there is a dramatic fall in the β_1 coefficients (figure 7).

4.2 Accounting for war shocks

Germany's experience during and immediately after the Second World War can be seen as a natural experiment to assess the consequence of disinvestment due to war-related destruction and dismantlement.[16] These disinvestments can be considered exogenous as they cannot be explained by economic factors, but are man-made consequences of political and military actions. To assess the effect of war-related disinvestment, we use a comparison of our baseline scenario and a scenario including the years 1944-48. The decision whether to include or exclude the period between 1944 and 1948 in our analysis has a dramatic effect on our results. As illustrated in figure 7, there was a dramatic decrease in our investment measures between 1945 and 1948 (outliers to the left); however, this collapse in investment was not mirrored in our measures of future well-being. Figure 7 also illustrates that the inclusion/exclusion of the war years has a considerable effect on the estimated relationship between GS and the present value of future changes in consumption.[17]

Conventional GS framework (tables 2 & 3) on its own cannot account for the future sustainability of the German economy, as is indicated by the outlying observations which combine massive disinvestment and surprisingly high future consumption values (that are subsequently discounted). Consequently, if outliers are included in the conventional GS framework, the estimated relationship between investment and present value of future changes in consumption are mis-represented, which is illustrated by the rather flat regression line (dotted line). If these outliers are excluded from the analysis in order to simulate a scenario where we are able to monetize the factors responsible for this residual, the line becomes steeper (solid line). We address this shortcoming of the analysis by incorporating the present value of TFP as a more inclusive measure of investment; this measure changes the slope of the regression coefficient significantly (see dashed line in figure 7).

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[16] Conversely, the First World War was not as destructive as the Second World War (De Long and Eichengreen 1991, p.22-23); Germany's economy was severely affected during 1914-19, but did not experience man-made destructions comparable to those occurred during 1944-48. As a result, the inclusion of 1914-19 has little impact on our results. Furthermore the early years of the Second World War were seen as a boom to Germany as its capital stock grew significantly (Kirner 1968). However, the final years of the War, Germany's economy suffered from massive war-related destructions, followed by post-war dismantlement.

[17] Using a 3 % discount rate gives an identical relationship to that discussed above.

As noted above, TFP incorporates all inputs not accounted for in the underlying production function, including social and institutional capital. In an historical overview of post-War Germany, Carr (1991) illustrates some significant institutional changes that occurred: Landmark trials of war criminals at Nuremburg (1945-6), followed by agreements to bolster German industry, Marshall Aid and Federal elections (1949). Dobbins (2003), in the more recent context of US efforts at nation-building in Iraq and Afghanistan, discusses factors important in the reconstruction efforts of Germany in the immediate aftermath of the Second World War. Important factors included democratization, military occupation and significant amounts of external assistance (calculated at $200 (2001 prices) per capita); the latter contrasts strongly with the Soviet occupation of the East where asset stripping was the norm. However, the key features in the reconstruction of the German economy, which contrasts strongly with more recent efforts in Somalia, Haiti and Afghanistan, was not that Germany was a highly developed economy returning to trend growth but rather that it had high levels of social capital; it was not divided ethnically, socio-economically or tribally (Dobbins 2003, p. 99). Olson (1982) argues that institutional and social changes were central to both German and Japanese post-war economic miracles. Furthermore, Dumke (1990) argues that institutional change and social capabilities were important factors in the German economy returning to its trend growth path.

De Long and Eichengreen (1991) offer another interpretation by arguing that there was more than a return to trend growth as post-WWII growth experience was akin to 'super growth'. Importantly they argue that the Marshall Plan was not significant in terms of bolstering capital stocks but rather its main influence came via a structural adjustment programme. They argue that impact of the Marshall plan came indirectly as it 'facilitated the negotiation of a pro-growth "social contract" that provided the political stability and climate necessary to support the postwar boom.' As with social capital for us, the "social contract" is ‘vital but is difficult to quantify’ (De Long and Eichengreen 1991, p. 6). Furthermore, these authors highlight that out of all the European reconstructing nations, Germany, the country with the strongest US influence, was the most successful performer in the post-War period. So the post-War period has multi-faceted institutional change but internally and externally which explain post-war economic growth and why GDP, and thus consumption, in Germany did not experience a collapse.

To investigate the role of intangible assets, such as social capital and institutions, we run two sets of regressions and show corresponding β1 coefficients, in one set we excluded the period 1944-48 while in the other set this period was included. These regressions aim at showing a correlation between investment metrics and future changes in consumption without bearing the risk of distortion by the difficulty of finding a monetary metric for social capital and institutions. We include the period 1944-48 in our analysis in the latter set of regressions to assess the suitability of TFP to capture the missing assets in the German economy that could explain why Germany’s future consumption rose although investment collapsed and turned highly negative during this period. Results shown in the first panel of table 4 are the ones derived in our baseline scenario, whereas results presented in the second panel additionally cover the period 1944-48.[18] The comparison of both panels indicates that conventional investment metrics, including GS, are affected by aforementioned distortion while the distortion is only modest for GreenTFP and GSTFP. This finding indicates that the monetized value of TFP is an important addition to conventional components of augmented saving and investment metrics.

When technology (TFP) is incorporated, the value of β_1 drops for all time horizons. In this case we also find that $\beta_1>0$ for 20 and 30-year time horizons and $\beta_1>1$ for time horizons

[18] Please note that results over 100 years are identical, as the years of 1944-48 are not included in either of the scenarios since corresponding future changes in consumption are unknown.

exceeding 30 years, and that this coefficient is closer to the size predicted by theory ($\beta_1 = 1$). The hypothesis that $\beta_1 = 1$ & $\beta_0 = 0$ jointly is rejected on the basis of this set of tests. Additionally, we apply a set of cointegration tests to assess a long-term relationship between aforementioned investment indicators and present value of future consumption at any given point in time. This measure helps us to assess this relationship from a different angle. We find that in our preferred 1.95 per cent scenario both series are cointegrated over 20, 30, and 100 years if conventional investment and GS metrics are considered. After additionally taking into account TFP, cointegration can be observed only for longer time spans (50 and 100 years).

4.3. Robustness tests: accounting for an alternative discount rates and territorial changes

As a first robustness check, we switch to an alternative discount rate of 3 per cent, which is based on real GDP growth of the German economy during the period under observation (table 5). For this scenario, we conclude again that the incorporation of present value of changes in future TFP improves the quality of the analysis. A comparison of values presented in column 3 (1948-48 period excluded) and column 4 (1944-48 period included) of Table 5 illustrates that investment metrics which do not incorporate TFP suffer from aforementioned distortion (for a comprehensive comparison see tables A1 & A2). Among the undistorted results of this set of regressions we also find a positive relationship ($\beta_1 > 0$) throughout all investments measures and time horizons. Here, empirical results are similar to the ones obtained in Table 2 that uses the benchmark 1.95% discount rate and also indicate the existence of a positive relationship between current investment and future utility ($\beta_1 > 0$). We also find that $\beta_1 > 0$ and $\rightarrow 1$ when additional forms of investment are considered over 20, 30, and 50 year time horizons. The opposite is true when looking at well-being changes over

100 years ahead: the value of β_1 for conventional net investment is fairly close to the predicted value of 1; incorporating additional forms of investment leads to a divergence of this coefficient from the value 1. Adding technological change confirms $\beta_1 > 0$, but not $\beta_1 > 0$ and $\rightarrow 1$. In the 3 per cent scenario we also reject the hypothesis that $\beta_1 = 1$ & $\beta_0 = 0$. For cointegration tests, we find conventional investment series are equally cointegrated with the present value of future consumption over 100 years, indicating that there is no particular advantage of adjusted net saving indicators in this regard.

As was seen in results presented in tables 2 to 5, they are sensitive to both time horizons and discount rates. Here we assess the role of discount rates in the prediction framework by expressing β1 coefficients, which are results of a set of regression models, as a function of a range of discount rates between 0.10 and 3 per cent. The variables affected by changing discount rates are the present value of future changes in consumption and also the present value of TFP. The results for the correlation between GS (incl. TFP) and the present value of future changes in consumption over 20, 30, 50, and 100 year spans are shown in figure 8.[19] For lower discount rates, β1 coefficients tend to be larger whereas for high discount rates the opposite is true. Moreover, the longer the time span under observation the sharper is the response (decline) in terms of β1 coefficient to increasing discount rates. Of all our time spans, the 100 year period is most sensitive to changes in the discount rate with β1 coefficients ranging from 6.05 to 0.37. Whereas the 20 year horizon is least sensitive to changing discount rates and at no discount rate do we discover a β1=1 relationship.

We also use this mechanism to identify an 'optimal' discount rate that is necessary to obtain the predicted β1 value of 1. For 20 and 30 years this is clearly impossible given that the starting levels are below 1. The 50 year horizon has a β1 coefficient equal to 1 at a

[19] Correlations between GS and the present value of future changes in consumption (incl. war years) show a similar story with the 100 year horizon most sensitive to choice of discount rate and 20 year horizon least sensitive. At no point does the 50 year horizon have a β1 coefficient equal to 1.

discount rate of approximately 3 per cent; the corresponding intersection point of the 100 year horizon is approximately 2.24 per cent. These coefficients enable us to evaluate how suitable our chosen discount rate is in the German case. The 1.95 per cent rate in our preferred scenario is based on real returns to German government bonds, while the results of our calibration exercises, shown in figure 8, suggest 2.24 per cent for 100 years horizon which is in close proximity to the rate suggested by historical national accounts, and 3 per cent is close to a long-run GDP growth rate.

We run another robustness test, simulating the continuous existence over the period under observation of the former Western part of Germany as it existed between 1945 and 1989 in order to address the multiple territorial changes which occurred over the period. The most important territorial changes include the temporary annexation of Alsace-Lorraine (1871-1918), as well as territorial losses after 1918/19 and 1945. Moreover, the figures used in this compilation for the post-1945 period do not include the East German economy. Accordingly, most statistics fall short of covering an "unchanged" German territory, potentially biasing the results of our empirical tests. To find appropriate metrics to weight Germany's territories, we use Maddison (1995) who reports the economic power for the territories that formed former Germany. For example, in 1936, the territory which later forms 'West Germany' accounts for 64 per cent of total economic power at the time. The territory that becomes 'East Germany' accounts for approximately 25 per cent; the territories east to the Oder-Neisse line account for the remaining 11 per cent. In 1990, the Western part of the re-united Germany accounts for approximately 90 per cent of the total figure. These weights are used to construct estimates of GDP, net investment, private consumption and pollution series for West Germany. We use Maddison's (1995) per-capital figures and census population figures provided by the Statistical Office of the German Empire (1910) to estimate the economic weight of the territories lost after WWI.

For resource extraction, figures are available allowing detailed adjustments even for smaller territorial units. Most significantly, territories east to the Oder-Neisse line accounted for approximately half of the hard coal extraction before WWI, and East Germany accounted for approximately 70 per cent of overall German brown coal production, but only 3 per cent of hard coal production. Other minerals and energy sources account for very little compared to hard and brown coal production. Accordingly, we subtract 70 per cent of brown coal production for the pre-1945 period, 3 per cent and 50 per cent of hard coal production for pre-1945 and pre-1918 period, respectively, to obtain a continuous West Germany series. For education expenditure, given the similar institutional standards we assume that per-capita expenditure was fairly similar throughout Germany. Therefore, we use shares of population in respective territories to identify education expenditures in West Germany. Territories ceded to Poland after WWI – other territories constitute a negligible share – account for approximately 4.4 per cent of Germany's population. East Germany and the territories annexed by Poland and the Soviet Union after WWII accounted for approximately 37 per cent of pre-war population (Maddison 1995, German census 1910). We adjust education expenditure using these population shares to obtain hypothetical West German data series. The result of this exercise confirms earlier results. Results are almost identical, irrespective whether the analysis is based on actual German figures, or on hypothetical West German ones (see Table 6).

5. Alternative indicators of well-being

The theory underlying the properties of GS as a sustainable development indicator relates the evolution of comprehensive wealth to future consumption paths. However, it has been argued that such conventional monetary-oriented welfare measures may be inaccurate when substantial shares of economic activity, such as subsistence farming or illicit markets are not included in official statistics. Alternative metrics may help to address this shortcoming and help to assess the wider implications of a country's long-term savings and investment strategy. We use infant mortality rate (IMR) and average male height to gain a fresh view on the impact of investment on future well-being in the long run. These metrics are frequently used as output-oriented proxies for living standards, reflecting the disease environment, nutritional standards and medical technology available (Baten and Blum, 2013; Gnegne, 2009). IMR is a non-monetary measure that reflects health standards but also informs about the health and education of women and poverty levels. Average height can be interpreted as net-nutrition; this is gross nutritional intake less energy requirements to deal with diseases, physical labour, quality of housing, etc.[20]

There is no defined theoretical relationship between alternative non-monetary indicators of well-being and GS that we can base hypothesis tests on. However, previous empirical studies have attempted to determine if in fact there is a correlation between GS and non-monetary indicators of well-being. Gnégé (2009) looks at the correlation between GS and changes in both IMR and the Human Development Index (HDI). Using data for 36 countries over the period 1971 to 2000, Gnégé (2009) estimated the relationship between changes in both IMR and HDI and GS over 5, 10 and 15 year time horizons. In general, Gnégé (2009) found a positive relationship between GS and future changes in IMR with coefficients ranging from 27.64 and 36.87 over 15 year time horizons. For HDI, coefficients ranged from 0.043 to 0.571 for 5 and 10 year horizons. Gnégé (2009) concluded that the results would be more consistent with theory if they could be tested over a longer time horizon. We thus first compare GS with corresponding values of IMR and average male height. Figures 9 and 10 illustrate how GS increases constantly prior to the Second World War, experiencing slumps

[20] There is a rich literature in this field, for example see: (Baten and Blum, 2012; Baten and Blum, 2013; Floud et al., 2011; Fogel et al., 1982; Komlos and Baten, 2004; Steckel, 1995).

during the First World War and economic crises in the 1920s and 1930s. After a substantial break with highly significant saving rates between 1944 and 1948 due to war-related effects, GS increased rapidly. Corresponding development in IMR and average height reflect this development only to some extent. IMR during the 19th century did not show a clear trend despite growing GS. Beginning in the early 20th century IMR fell rapidly, with a modest increase during the Second World War. After 1948, GS increased substantially while the velocity of IMR declines slowed down.

Similar development can be observed for average height: average height does not follow a clear trend until the late 19th century. The series indicates rising average heights until 1914, when food shortages led to deteriorating living standards during First World War. During the interwar period, economic turmoil and the Nazi government's autarchy policy put downwards pressure on nutritional and health standards in Germany (Baten and Wagner, 2003; Blum, 2011; Blum, 2013b). The Second World War did not lead to decreasing heights, but hindered further improvements. Between 1945 and the 1960s German heights experienced substantial increases due to improvements in food quantities and quality, as well as medical advances and reduced physical work burden.

Interestingly, substantial increases in GS during the 1980s did not lead to increases in IMR and average height of the same magnitude. The reason for this apparent contradiction lies in the nature of the target variable which is supposed to reflect outcomes of previous investments. The measurement space in both anthropometric metrics has natural and biological limits. IMR cannot improve beyond zero, and average height is not likely to be outside a certain biological minimum and maximum. We do not have evidence on a German minimum height, but average height values reached towards the end of the height series indicate that a biological limitation is close. On the other hand, investment does not face similar boundaries as it can – at least in theory – grow almost infinitely, since its value is determined not only by quantity but also but its price. Any analysis combining previous investments and future anthropometric outcomes needs to take this phenomenon into account.

Following Gnégé (2009), we have tested for the correlation between both future changes in infant mortality rates and average heights and our GS measure. We calculate measures of changes of 5, 10, 20, 30 and 50 year time horizons, and have tested over shorter horizons (5 and 10) to correspond with the horizons tested by Gnégé (2009). Our null hypothesis is that positive levels of GS per capita at time t should be associated with improving measures of IMR and height at some future period. Both anthropometric metrics are ordered by time of birth. While this procedure is straightforward in the case of IMR, the rationale to do this for average height is that the crucial period for the determination of final average height is the first three years in life. The results, presented in tables 7 and 8, are intuitive as the shorter the time horizon the less likely we are to find a strong correlation between changes in our well-being indicators and our measures of GS. What we do find though are that the size of the coefficients increase significantly the longer the time period considered, from 1.311 to 34.72 in the case of GS and 2.704 to 48.93 for the case of GSTFP thus emphasizing the importance of long-run analyses for capturing the full effect of comprehensive investment metrics on future well-being. With average heights we find that the shorter time horizons (5 and 10 years) perform very poorly. But as the time horizons increase we see stronger positive relationships between future changes in heights and GS. In the case of GSTFP we find an even stronger relationship with future changes in heights and also significant cointegrating relationships. However, in the case of IMR we do not find evidence of cointegration relationships. In sum, although this methodology differs from the conventional strategy of capturing future changes in well-being, they do indicate that there is a positive correlation between GS and future changes in well-being, however it is defined.

6. Discussion and Conclusions

In this paper we have constructed long-run estimates of savings-based sustainability indicators for Germany over the period 1850 to 2000. We found that over this period, German GS rates were positive for the most part except for the two World Wars and the Great Depression. We also tested the predictive power of GS by constructing tests of the relationship between comprehensive wealth measures and the present value of future changes in consumption.

The results presented in tables 2 to 4 found that increasingly comprehensive indicators of sustainability were good predictors of future changes in well-being. For example, the β1 coefficients of our GSTFP metric (GS including TFP) ranged from 0.575-1.380 excluding years 1944-48 and 0.575-1.380 including years 1944-48. Our results were sensitive to both time-horizon and discount rate, in line with the findings of Greasley et al (2014). In the German case, our results were also very sensitive to the effects of wars as these had dramatic effects on both investment and consumption. However, including the present value of changes in total factor productivity as a means of picking up changes in technology and social capital in the course and immediate aftermath of the war changes the relationship between net investment and future consumption, and helps us to understand the positive German consumption pattern despite the major physical destructions and dismantlement which occurred during and after the Second World War.

Another contribution of this paper was to analyse the relationship between GS and alternative measures of well-being, average heights and infant mortality. The framework developed by Ferreira et al. (2008) of a one-for-one relationship between increases in GS and well-being does not automatically transfer, as these anthropometric variables have natural limits. The comparison between GS and heights or infant mortality differs conceptually from conventional comparisons of GS and monetary based measures of well-being, yet we believe that applying alternative metrics of well-being may be a fruitful exercise, despite the fact that a careful investigation of the feasibility of these metrics is necessary before using them as "well-being" measures. In fact, we found a positive correlation between future changes in both IMR and heights and our GS metrics.

Future directions for research would be to see how the German historical experience compares with other Western economies, such as Britain and the US. The three countries were part of an increasingly integrated global economy and all shocks outlined here for Germany, such as World Wars and the Great Depression, were felt in the Anglo-American sphere as well. Also, during most of the war and inter-war period the French economy had similar experiences as the German economy; so that a comparison of Germany and France with respect to their ability to maintain their consumption paths might help understanding preconditions to deal with economic shocks. Thus isolating the common shocks may help provide a better trans-national understanding of sustainability that may be hidden by idiosyncratic country histories. Alternative measures of changes in human capital could also be incorporated into this framework to get a better understanding of the role of human capital development in long-run development. Education expenditure, the measure used here, is a partial measure and does not take account of depreciation or other determinants of human capital formation. A useful pathway for future research could be the application of alternative measures such as the discounted lifetime earnings to more fully account for human capital development.

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Table 1: Decadal averages of Sustainability indicators (% of GDP)

	Net	Green	GS	GS carbon	GS + TFP	Green+ TFP
	%	%	%	%	%	%
1850s	8.25	7.88	8.60	8.59	23.76	24.10
1860s	10.26	9.78	10.66	10.64	26.49	24.95
1870s	11.79	11.06	12.13	12.10	28.44	27.17
1880s	10.89	10.06	11.47	11.43	33.65	28.66
1890s	13.29	12.14	13.73	13.67	37.99	32.41
1900s	13.96	12.41	14.38	14.27	42.01	37.07
1910s	13.64	11.57	13.65	13.50	59.29	45.23
1920s	9.69	8.29	9.90	9.74	54.72	49.02
1930s	7.04	5.85	8.73	8.57	62.99	53.83
1940s	***-9.51***	***-10.71***	***-8.60***	***-8.82***	47.13	45.00
1950s	16.92	13.80	16.60	16.23	70.12	66.69
1960s	17.11	15.70	19.55	19.22	57.63	57.89
1970s	10.92	10.17	15.86	15.54	45.87	42.93
1980s	8.08	7.52	12.65	12.34	41.00	35.15
1990s	6.51	6.47	10.73	10.49	36.61	31.85
1850-2000	9.90	8.78	11.33	11.16	44.60	40.18

Table 2: Estimated parameter values for alternative measures of investment when future wellbeing is measured by the PV of consumption per capita over 20-100 years horizons, 1.95 per cent / year discount rate (excluding 1944-48)

Dependent variable	Independent variable	β1	Standard error	β0	Standard error	N	β1=1	β0=0; & β1=1	ADF	R^2	Sample
PV Cons. 20	Net	2.370***	(0.155)	-772.5***	(239.1)	135	78.35***	56.99***	-3.020**	0.638	1850-1989
PV Cons. 30		3.318***	(0.212)	-1,042***	(292.7)	125	119.58***	93.41***	-2.885**	0.666	1850-1979
PV Cons. 50		4.196***	(0.654)	-466.5	(594.3)	105	23.87***	32.66***	-2.253	0.285	1850-1959
PV Cons. 100		3.356***	(0.233)	355.0**	(154.9)	60	101.97***	420.48***	-3.189**	0.781	1850-1909
PV Cons. 20	Green	2.428***	(0.173)	-558.6**	(245.6)	135	68.20***	54.62***	-2.961**	0.597	1850-1989
PV Cons. 30		3.488***	(0.239)	-836.0***	(300.4)	125	108.00***	89.45***	-2.950**	0.633	1850-1979
PV Cons. 50		4.145***	(0.789)	-36.15	(628.2)	105	15.88***	28.52***	-2.330	0.211	1850-1959
PV Cons. 100		3.629***	(0.288)	366.8**	(174.8)	60	83.44***	361.19***	-2.909**	0.733	1850-1909
PV Cons. 20	GS	1.674***	(0.106)	-361.5*	(213.1)	135	40.49***	29.58***	-2.662*	0.652	1850-1989
PV Cons. 30		2.455***	(0.167)	-484.2*	(279.3)	125	76.33***	63.08***	-2.487	0.639	1850-1979
PV Cons. 50		4.150***	(0.66)	-538.3	(613.6)	105	22.78***	31.36***	-2.579*	0.277	1850-1959
PV Cons. 100		3.279***	(0.226)	327.6**	(155.2)	60	101.77***	416.19***	-3.107**	0.784	1850-1909
PV Cons. 20	GScarbon	1.709***	(0.109)	-368.8*	(214.8)	135	42.26***	31.12***	-2.672*	0.649	1850-1989
PV Cons. 30		2.500***	(0.171)	-493.6*	(281.5)	125	77.06***	63.90***	-2.508	0.635	1850-1979
PV Cons. 50		4.133***	(0.677)	-486.7	(621.1)	105	21.43***	30.55***	-2.556	0.266	1850-1959
PV Cons. 100		3.298***	(0.229)	324.9**	(156.6)	60	100.63***	412.15***	-3.087**	0.781	1850-1909

Note: "PV Cons. N" refers to the present value of changes in future consumption over a N year horizon. In the columns β1=1 and β0=0 &β1=1 the results of a set of Wald-tests are reported which indicate whether aforementioned hypotheses in regard to size of β0 and β1 have to be rejected. Statistically significant coefficients suggest rejection. In the column labelled ADF results of a set of Augmented Dickey Fuller statistic which was used to perform the Engle-Granger (1987) two-step method to test for cointegration. Statistically significant values indicate a cointegrated relationship. The degree of augmentation is determined by the Hannan-Quinn Information Criteria. ***, **, and * indicate rejection of the null of non-stationary residuals at the 1%, 5%, and 10% level, respectively.

Table 3: Estimated parameter values for alternative measures of investment when future wellbeing is measured by the PV of consumption per capita over 20-100 years horizons, 1.95 per cent / year discount rate (including 1944-48)

Dependent variable	Independent variable	β1	Standard error	β0	Standard error	N	β1=1	β0=0; & β1=1	ADF	R^2	Sample
PV Cons. 20	Net	1.408***	(0.173)	621.0**	(276)	140	5.54**	17.42***	-2.235	0.324	1850-1989
PV Cons. 30		1.636***	(0.253)	1,128***	(366.1)	130	6.30**	24.45***	-1.674	0.246	1850-1979
PV Cons. 50		0.063	(0.479)	3,099***	(500.4)	110	3.82*	22.48***	0.270	0	1850-1959
PV Cons. 100		3.356***	(0.233)	355.0**	(154.9)	60	101.97***	420.48***	-3.189**	0.781	1850-1909
PV Cons. 20	Green	1.384***	(0.186)	807.5***	(274.6)	140	4.28**	19.20***	-2.140	0.287	1850-1989
PV Cons. 30		1.596***	(0.272)	1,343***	(362.8)	130	4.81**	25.45***	-1.564	0.212	1850-1979
PV Cons. 50		-0.301	(0.501)	3,313***	(480.3)	110	6.73**	25.58***	1.167	0.003	1850-1959
PV Cons. 100		3.629***	(0.288)	366.8**	(174.8)	60	83.44***	361.19***	-2.909**	0.733	1850-1909
PV Cons. 20	GS	1.219***	(0.122)	522.7**	(247)	140	3.25*	11.66***	-2.130	0.421	1850-1989
PV Cons. 30		1.515***	(0.199)	1,016***	(342.1)	130	6.67**	22.77***	-1.695	0.311	1850-1979
PV Cons. 50		0.0774	(0.486)	3,088***	(512.3)	110	3.61*	21.89***	0.141	0	1850-1959
PV Cons. 100		3.279***	(0.226)	327.6**	(155.2)	60	101.77***	416.19***	-3.107**	0.784	1850-1909
PV Cons. 20	GScarbon	1.232***	(0.125)	536.5**	(248.7)	140	3.45*	12.24***	-2.130	0.414	1850-1989
PV Cons. 30		1.520***	(0.204)	1,037***	(343.9)	130	6.53**	22.94***	-1.686	0.303	1850-1979
PV Cons. 50		0.0217	(0.488)	3,126***	(510.6)	110	4.01**	22.25***	0.276	0	1850-1959
PV Cons. 100		3.298***	(0.229)	324.9**	(156.6)	60	100.63***	412.15***	-3.087**	0.781	1850-1909

Note: see table 2.

Table 4: Estimated parameter values for alternative measures of investment when future wellbeing is measured by the PV of consumption per capita over 20-100 years horizons, 1.95 per cent / year discount rate (including 1944-48)

Dependent variable	Independent variable	β1	Standard error	β0	Standard error	N	β1=1	β0=0; & β1=1	ADF	R^2	Sample
(1.) Excluding 1944-48											
PV Cons. 20	GreenTFP	0.648***	(0.0345)	-882.1***	(205.2)	134	103.90***	239.43***	-2.347	0.728	1851-1989
PV Cons. 30		0.936***	(0.0467)	-1,192***	(241.9)	124	1.89	46.80***	-2.659*	0.767	1851-1979
PV Cons. 50		1.549***	(0.101)	-1,660***	(355.2)	104	29.60***	14.88***	-2.972**	0.698	1851-1959
PV Cons. 100		1.460***	(0.064)	145.1	(108.2)	59	51.66***	222.62***	-3.407 **	0.901	1851-1909
PV Cons. 20	GSTFP	0.575***	(0.0306)	-758.3***	(200.3)	134	193.38***	344.67***	-2.380	0.728	1851-1989
PV Cons. 30		0.842***	(0.0433)	-1,041***	(242.4)	124	13.31***	68.26***	-2.585*	0.756	1851-1979
PV Cons. 50		1.495***	(0.0976)	-1,685***	(357.1)	104	25.72***	13.34***	-3.029**	0.697	1851-1959
PV Cons. 100		1.380***	(0.0593)	169.1	(105.2)	59	41.08***	191.55***	-3.393**	0.905	1851-1909
(2.) Including 1944-48											
PV Cons. 20	GreenTFP	0.607***	(0.0383)	-555.3**	(225.7)	139	104.96***	184.14***	-2.472	0.647	1851-1989
PV Cons. 30		0.861***	(0.0573)	-660.9**	(294.4)	129	5.90**	24.07***	-2.398	0.639	1851-1979
PV Cons. 50		1.327***	(0.135)	-620.7	(478.1)	109	5.85**	3.54**	-2.449	0.474	1851-1959
PV Cons. 100		1.460***	(0.064)	145.1	(108.2)	59	51.66***	222.62***	-3.407**	0.901	1851-1909
PV Cons. 20	GSTFP	0.542***	(0.0338)	-460.1**	(218.9)	139	183.31***	270.96***	-2.289	0.652	1851-1989
PV Cons. 30		0.781***	(0.0523)	-551.5*	(290.2)	129	17.51***	39.87***	-2.173	0.637	1851-1979
PV Cons. 50		1.294***	(0.13)	-685.9	(478.5)	109	5.10**	2.78*	-2.432	0.48	1851-1959
PV Cons. 100		1.380***	(0.0593)	169.1	(105.2)	59	41.08***	191.55***	-3.393**	0.905	1851-1909

Table 5: Alternative discount rates, 1.95% and 3%

		(1)		(2)	(3)		(4)
		Excl. 1944-48		**Incl. 1944-48**	**Excl. 1944-48**		**Incl. 1944-48**
		1.95%		**1.95%**	**3%**		**3%**
PV Cons. 20	Net	2.370***	>	1.408***	2.157***	>	1.286***
PV Cons. 30		3.318***	>	1.636***	2.880***	>	1.427***
PV Cons. 50		4.196***	>	0.063	3.365***	>	0.0601
PV Cons. 100		3.356***	√	3.356***	0.839***	√	0.839***
PV Cons. 20	Green	2.428***	>	1.384***	2.212***	>	1.265***
PV Cons. 30		3.488***	>	1.596***	3.026***	>	1.393***
PV Cons. 50		4.145***	>	-0.301	3.328***	>	-0.23
PV Cons. 100		3.629***	√	3.629***	0.894***	√	0.894***
PV Cons. 20	GS	1.674***	>	1.219***	1.525***	>	1.114***
PV Cons. 30		2.455***	>	1.515***	2.132***	>	1.320***
PV Cons. 50		4.150***	>	0.0774	3.294***	>	0.0596
PV Cons. 100		3.279***	√	3.279***	0.815***	√	0.815***
PV Cons. 20	GScarbon	1.709***	>	1.232***	1.556***	>	1.125***
PV Cons. 30		2.500***	>	1.520***	2.171***	>	1.325***
PV Cons. 50		4.133***	>	0.0217	3.281***	>	0.0155
PV Cons. 100		3.298***	√	3.298***	0.819***	√	0.819***
PV Cons. 20	GreenTFP	0.648***	>	0.607***	0.636***	>	0.591***
PV Cons. 30		0.936***	>	0.861***	0.871***	>	0.793***
PV Cons. 50		1.549***	>	1.327***	1.303***	>	1.079***
PV Cons. 100		1.460***	√	1.460***	0.395***	√	0.395***
PV Cons. 20	GSTFP	0.575***	>	0.542***	0.558***	>	0.524***
PV Cons. 30		0.842***	>	0.781***	0.778***	>	0.715***
PV Cons. 50		1.495***	>	1.294***	1.253***	>	1.052***
PV Cons. 100		1.380***	√	1.380***	0.372***	√	0.372***

Note: Please see tables 2 and 4 for additional information on these empirical tests. See also table 1.

Table 6: Comparison of $\beta 1$ coefficients for West Germany only

		(1)		(2)	(3)		(4)
		Excl. 1944-48		**Incl. 1944-48**	**Excl. 1944-48**		**Incl. 1944-48**
		1.95%		**1.95%**	**3%**		**3%**
PV Cons. 20	Net	2.330***	>	1.070***	2.127***	>	0.983***
PV Cons. 30		3.307***	>	1.163***	2.913***	>	1.040***
PV Cons. 50		4.418***	>	-0.179	3.621***	>	-0.137
PV Cons. 100		3.925***	√	3.925***	1.265***	√	1.265***
PV Cons. 20	Green	-2.316***	>	-1.109***	-2.114***	>	-1.018***
PV Cons. 30		-3.271***	>	-1.216***	-2.885***	>	-1.088***
PV Cons. 50		-4.342***	>	0.183	-3.622***	>	0.125
PV Cons. 100		-4.184***	√	-4.184***	-1.339***	√	-1.339***
PV Cons. 20	GS	-2.958***	>	-0.778***	-2.704***	>	-0.720***
PV Cons. 30		-4.239***	>	-0.844**	-3.750***	>	-0.769***
PV Cons. 50		-3.964***	>	0.495	-3.399***	>	0.366
PV Cons. 100		-4.656***	√	-4.656***	-1.476***	√	-1.476***
PV Cons. 20	GScarbon	-2.875***	>	-1.007***	-2.627***	>	-0.928***
PV Cons. 30		-3.952***	>	-1.086***	-3.491***	>	-0.978***
PV Cons. 50		-4.317***	>	0.231	-3.649***	>	0.155
PV Cons. 100		-4.520***	√	-4.520***	-1.442***	√	-1.442***
PV Cons. 20	GreenTFP	1.104***	>	0.989***	1.134***	>	0.982***
PV Cons. 30		1.730***	>	1.474***	1.697***	>	1.382***
PV Cons. 50		2.768***	>	2.048***	2.428***	>	1.719***
PV Cons. 100		3.635***	√	3.635***	1.447***	√	1.447***
PV Cons. 20	GSTFP	0.570***	>	0.534***	0.553***	>	0.514***
PV Cons. 30		0.882***	>	0.814***	0.820***	>	0.749***
PV Cons. 50		1.787***	>	1.568***	1.530***	>	1.299***
PV Cons. 100		1.584***	√	1.584***	0.551***	√	0.551***

Note: Full tables including cointegration tests are not shown here due to space restrictions. See also table 1.

Table 7: Estimated parameter values for investment indicators and future changes in infant mortality rates

Dependent variable	Independent variable	β1	Standard error	β0	Standard error	R2	ADF	Sample
Δimr5	lnGS	1.311	(2.218)	-18.17	(15.47)	0.014	-4.070**	1850-1993
Δimr10		2.45	(2.906)	-36.83*	(20.09)	0.036	-2.678*	1850-1988
Δimr20		10.21***	(3.445)	-114.1***	(23.62)	0.203	-2.727*	1850-1978
Δimr30		19.39***	(3.903)	-197.4***	(26.5)	0.44	-1.585	1850-1968
Δimr50		34.72***	(8.023)	-335.2***	(53.3)	0.502	-1.573	1850-1948
Δimr100		28.94***	(7.863)	-420.0***	(48.78)	0.365	-1.618	1850-1898
Δimr5	lnGSTFP	2.704	(2.298)	-32.35*	(18.5)	0.011	-4.114***	1851-1993
Δimr10		3.789	(2.795)	-51.81**	(22.5)	0.014	-2.998**	1851-1988
Δimr20		12.64***	(3.041)	-145.9***	(24.45)	0.121	-3.576***	1851-1978
Δimr30		22.32***	(3.244)	-243.5***	(25.88)	0.283	-2.101	1851-1968
Δimr50		48.93***	(5.387)	-487.8***	(42.28)	0.429	-2.334	1851-1948
Δimr100		45.51***	(8.717)	-566.5***	(62.45)	0.372	-1.978	1851-1898

Table 8: Estimated parameter values for investment indicators and future changes in average male heights

Dependent variable	Independent variable	β1	Standard error	β0	Standard error	R2	ADF	Sample
Δheight5	lnGS	-0.15	(0.236)	1.867	(1.553)	0.004	-4.093 ***	1850-1974
Δheight 10		-0.00573	(0.281)	1.449	(1.848)	0	-3.466***	1850-1969
Δheight 20		0.313	(0.345)	0.565	(2.253)	0.009	-2.189	1850-1959
Δheight 30		0.667*	(0.362)	-0.34	(2.355)	0.036	-1.494	1850-1949
Δheight 50		1.571***	(0.377)	-3.271	(2.427)	0.186	-1.807	1850-1929
Δheight5	lnGSTFP	0.149	(0.179)	-0.3	(1.398)	0.006	-4.433***	1851-1974
Δheight 10		0.404*	(0.224)	-1.704	(1.741)	0.03	-3.814***	1851-1969
Δheight 20		1.048***	(0.257)	-5.408***	(1.984)	0.143	-3.050**	1851-1959
Δheight 30		1.552***	(0.262)	-7.825***	(2.01)	0.27	-2.434	1851-1949
Δheight 50		2.176***	(0.299)	-9.476***	(2.247)	0.408	--3.404**	1851-1929

Figure 1: German net investment as a percentage of GDP, 1850-2000

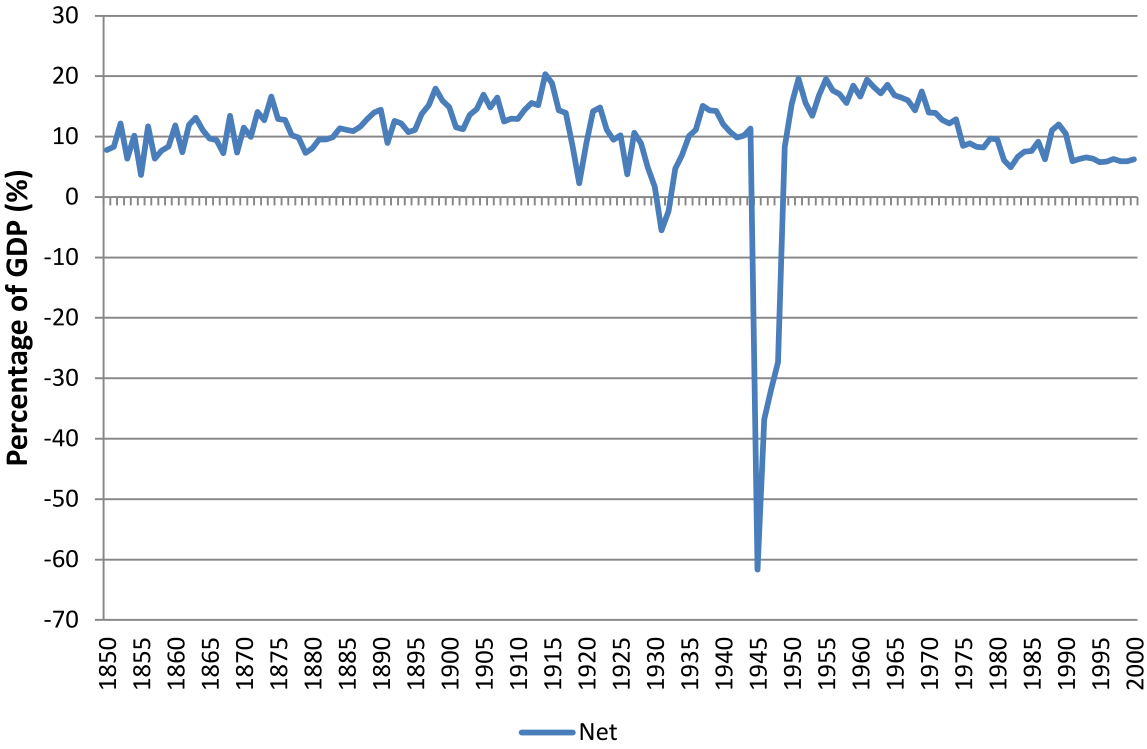


Figure 2: Resource depletion (at market prices and shadow prices) as a percentage of GDP, 1850-2000

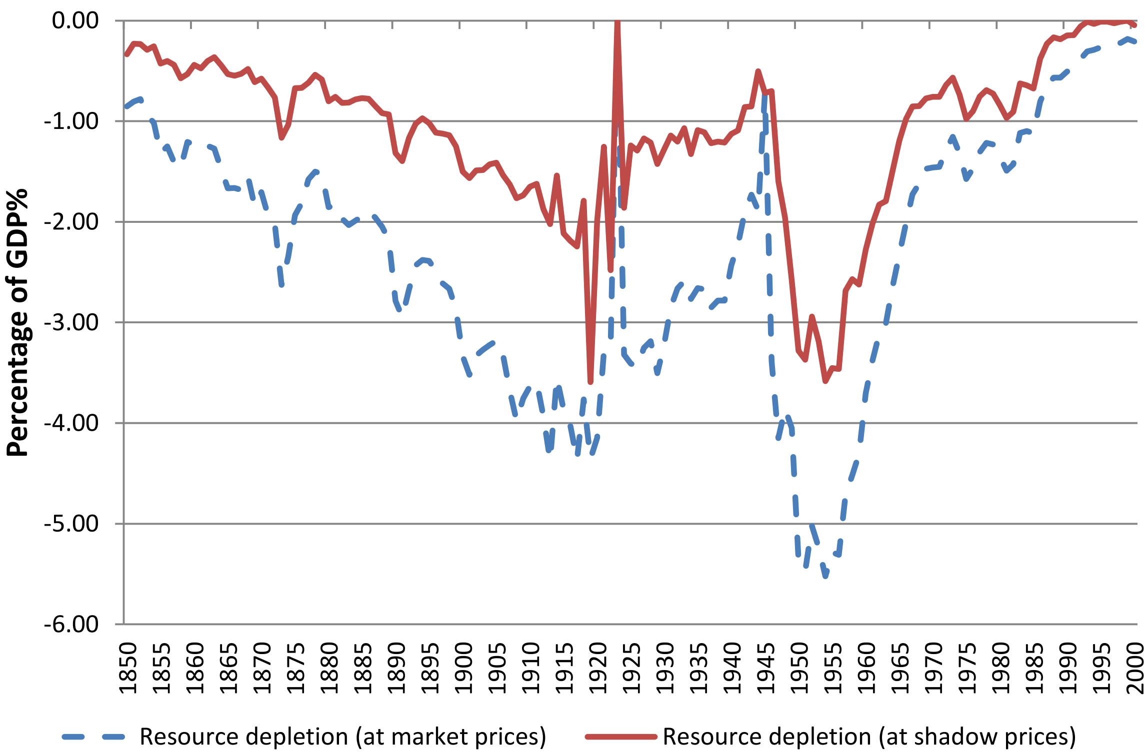


Figure 3: Trends in education spending

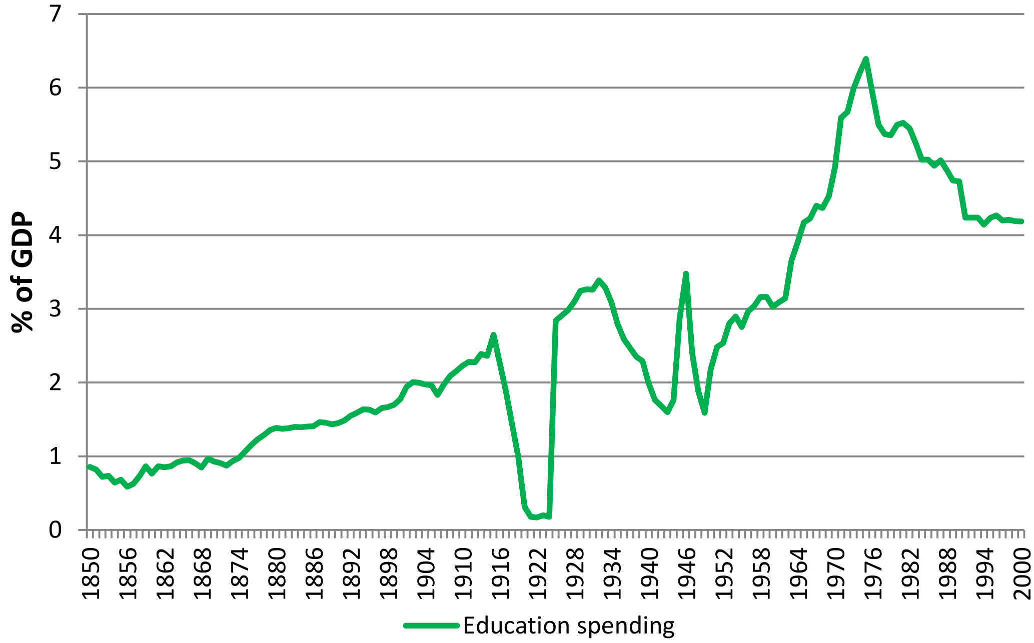
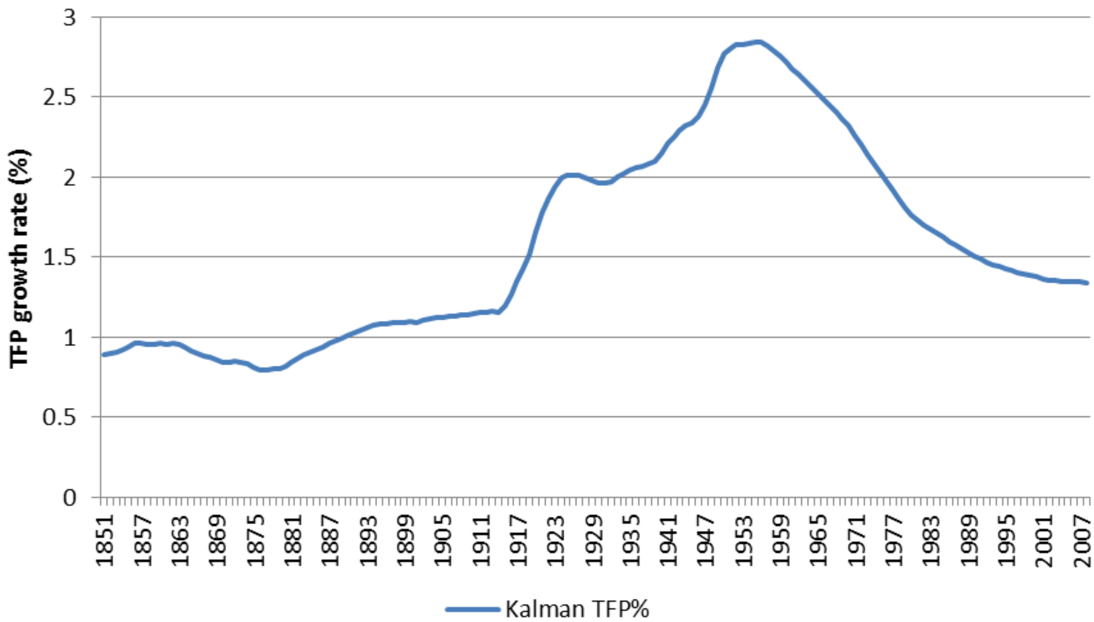


Figure 4: German trend TFP growth, 1851-2008



Note: Data on labour hours worked and real GDP is taken from Hoffman (1965) and Greasley and Madsen (2006). Information on capital stock for the period 1850 through 2000 is provided by Metz (2004). Missing values during and after the Second World War have been estimated on the basis of Krengel (1958). Factor shares used were from Greasley and Madsen (2006), labour share of 0.63 and a capital share of 0.37 based on average labour share of GDP from 1850-2008. A Kalman filter of the TFP growth rate was estimated, this was used to calculate the present value of TFP's contribution to GDP growth (in line with Pezzey et al (2006)).

Figure 5: Present value future changes in consumption per capita, (1990 DM, 1.95% discount rate)

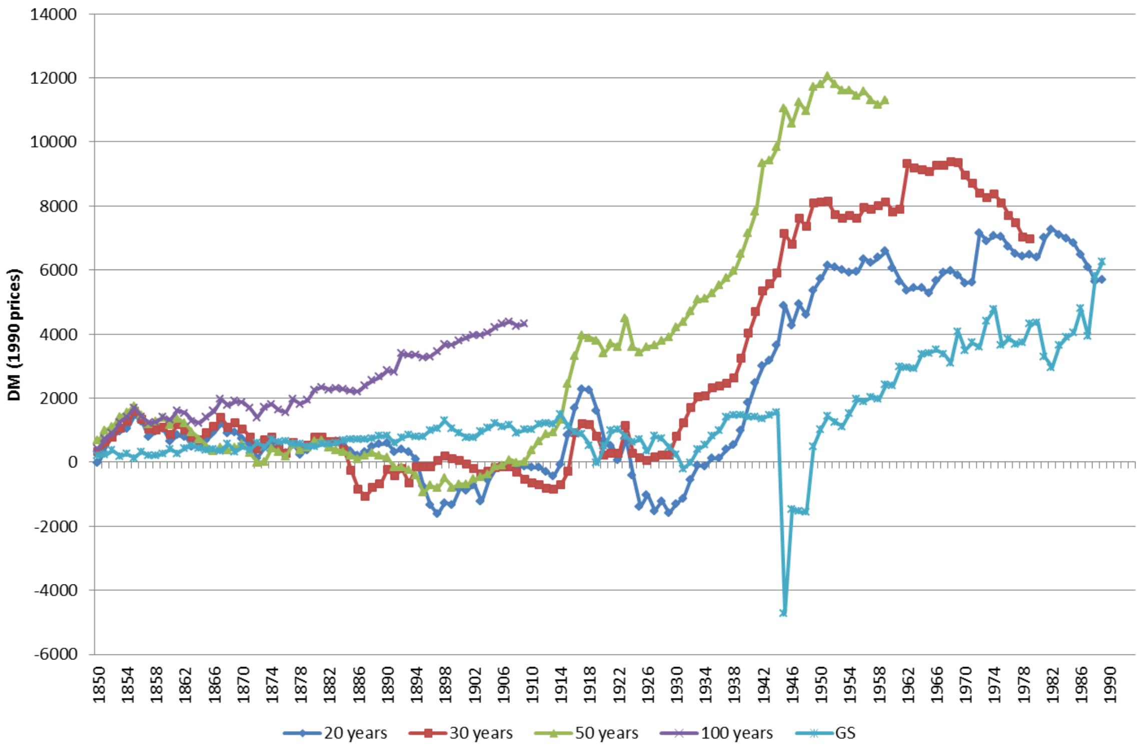


Figure 6a: Net, Green and GS in Germany, 1850-2000

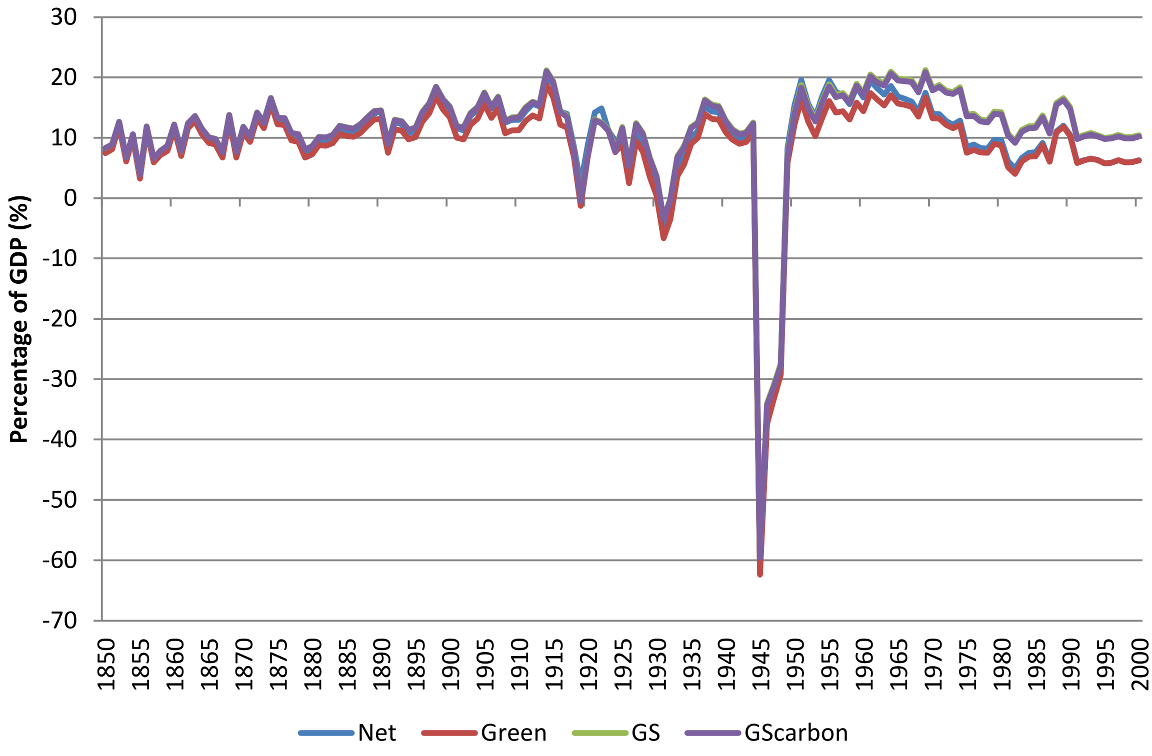


Figure 6b: Genuine Savings with and without the present value of changes in TFP 1851-2000 (discounted 1.95% over 20 years)

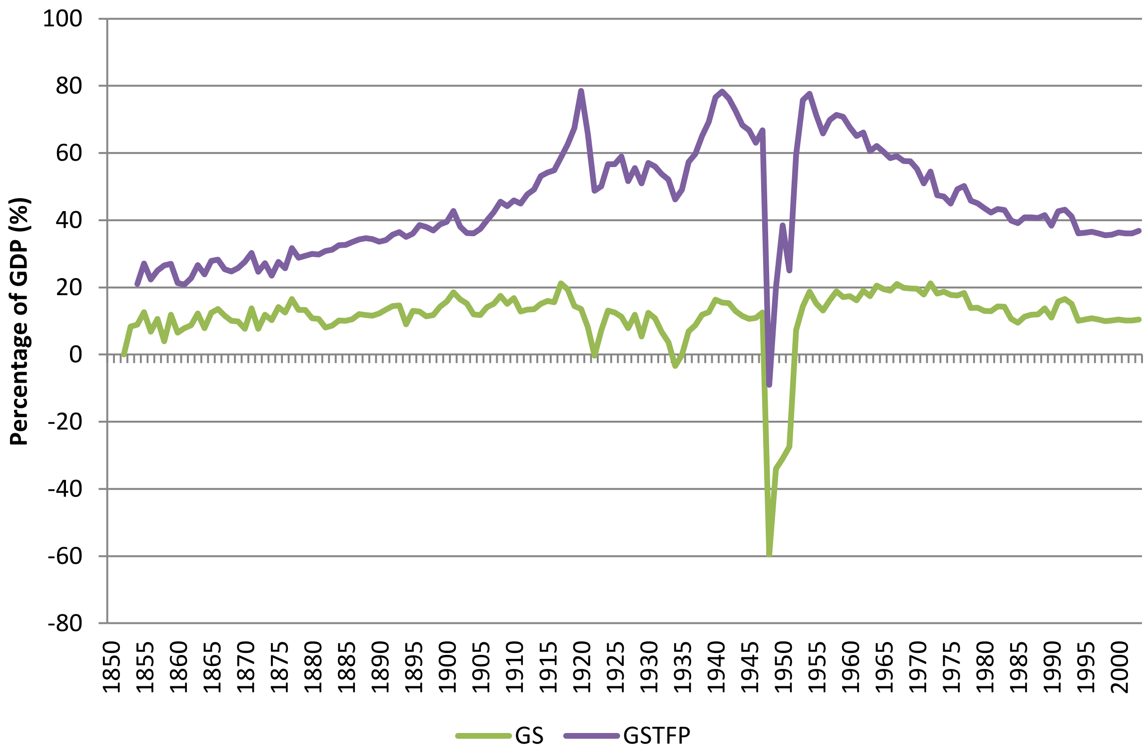


Figure 6 c: Genuine Savings per capita (with and without the present value of changes in TFP) 1851-2000

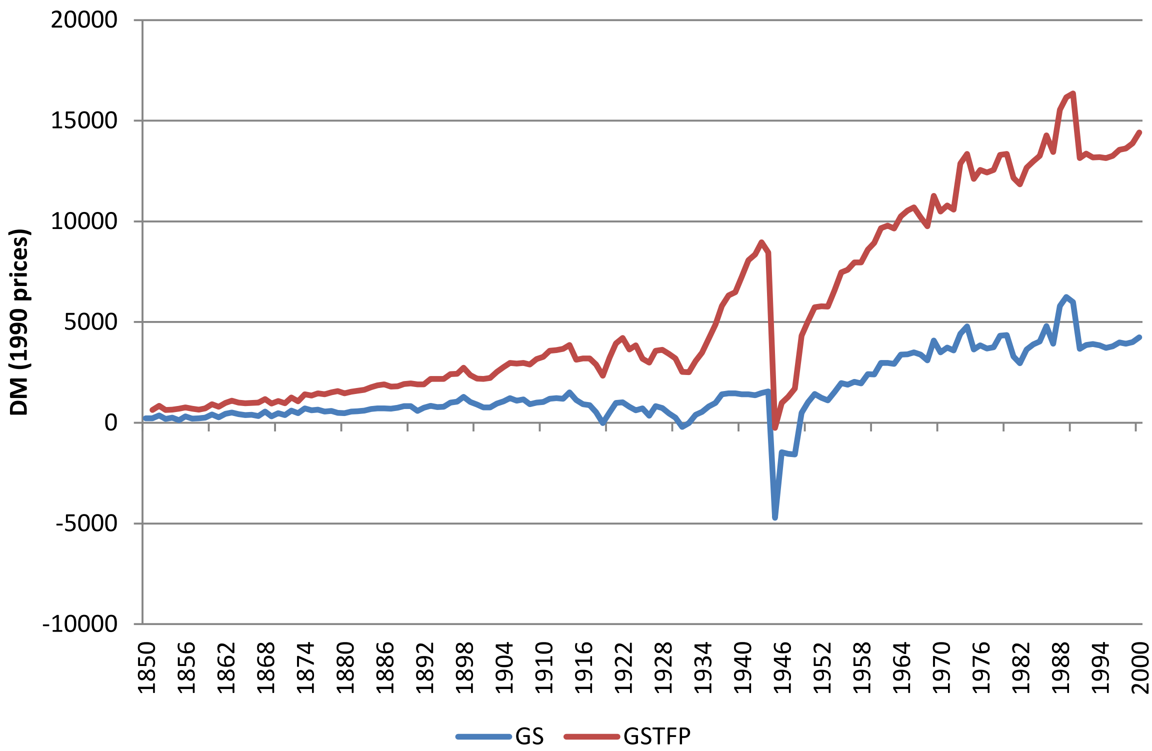


Figure 7: Investment and future consumption over 50 years (1.95% discount rate)

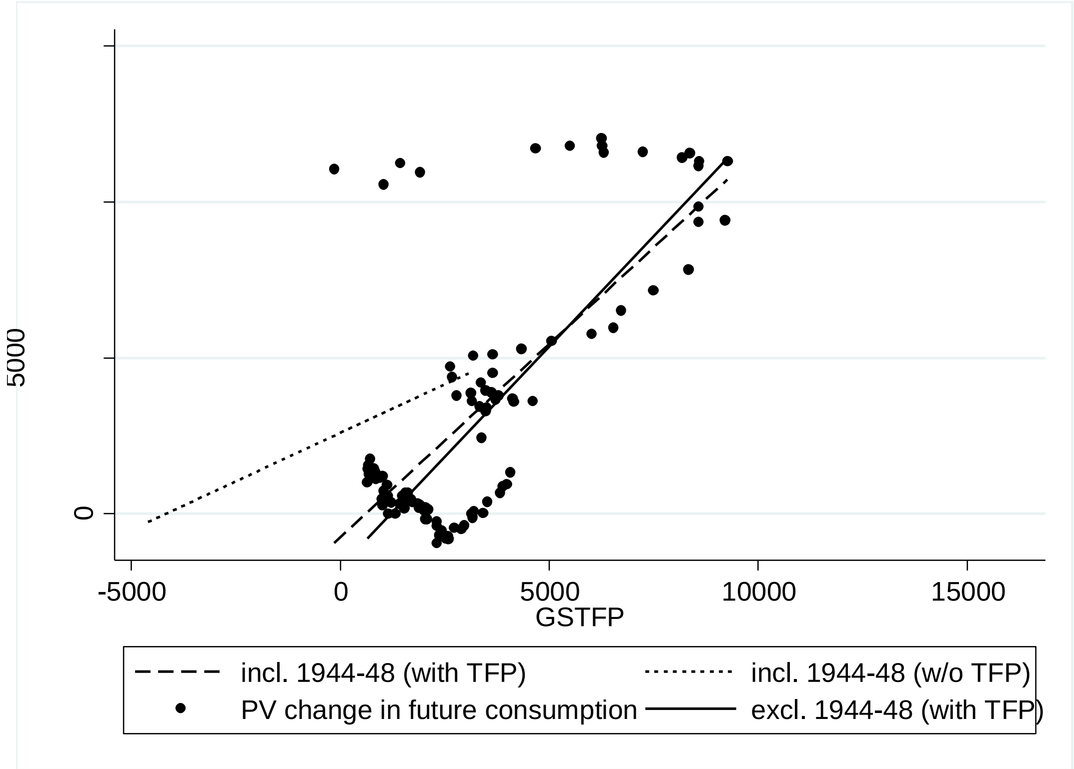


Figure 8: β1 coefficients by time horizon as a function of the discount rate applied

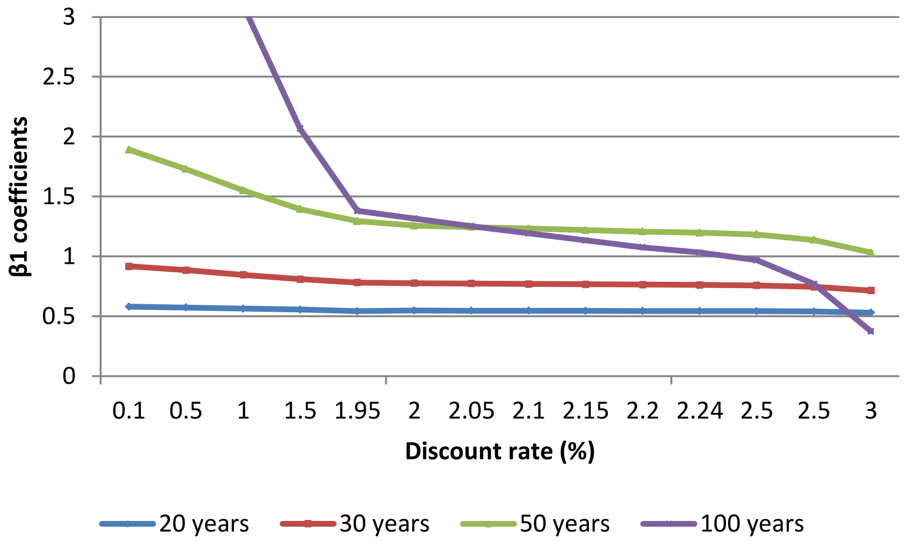


Figure 9: Infant Mortality Rate and Genuine Savings in Germany, 1850-2000

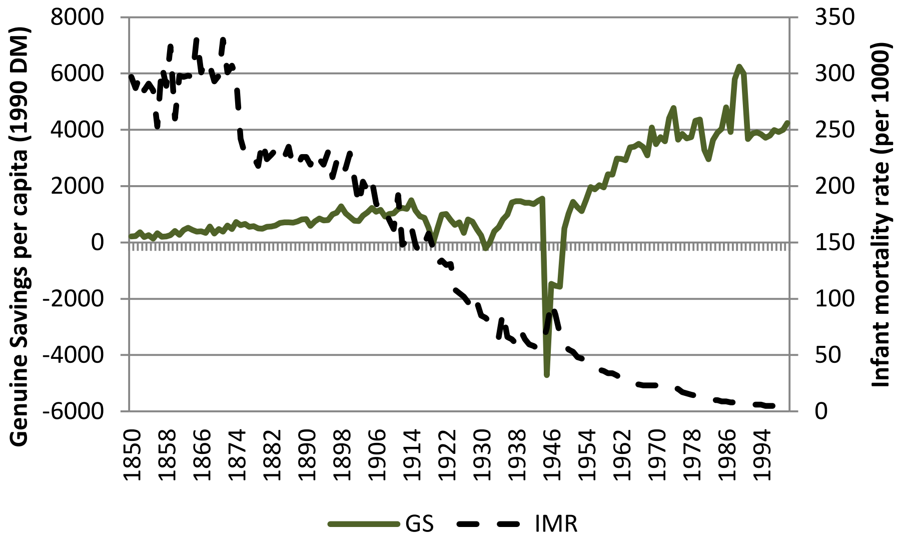
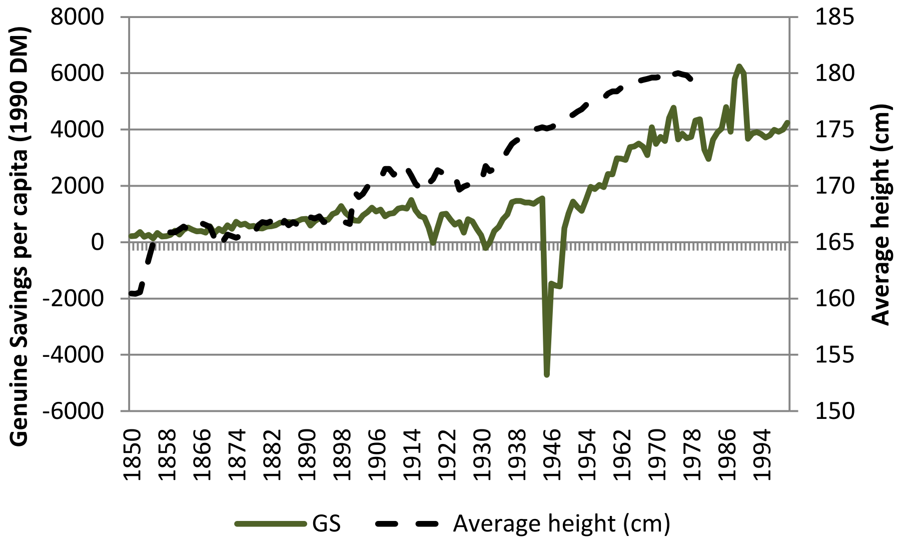


Figure 10: Average height (in cm) in Germany and Genuine savings per capita, 1850-2000



Data appendix

Table 1a: Descriptive statistics (refer to results presented in table 2):

	N	Mean	Median	Standard Deviation	Minimum	Maximum
Net investment	151	1209.17	961.84	1171.45	-4883.35	4527.06
Green	151	1100.75	847.24	1136.14	-4940.30	4456.82
Genuine Savings (GS)	151	1559.38	990.55	1628.96	-4713.19	6245.64
GS carbon	151	1529.91	975.93	1596.84	-4717.17	6133.14
GS TFP	150	5551.64	3253.44	4694.88	-256.09	16352.83
Green TFP	150	5090.10	3151.64	4139.48	-483.19	14473.07
PVC 20 years	140	2182.26	757.70	2841.71	-1620.85	7275.89
PVC 30 years	130	2735.24	983.69	3511.25	-1073.66	9360.81
PVC 50 years	110	3141.31	1179.44	4033.04	-944.89	12046.91
PVC 100 years	60	2375.34	2085.09	1070.67	421.86	4381.07

Note: All investment measures are corrected for population changes; consumption: present value of future private consumption.

<u>Data sources</u>

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).[21] 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 (DeutscheBundesbank, 1998, 2005). Remaining missing values were estimated using trade balances as a proxy for capital flows (DeutscheBundesbank, 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 (Bundesamt, 2013), Ritschl (2005), Abelshauser (1998), and Harrison (1988).

Average height data are taken from the following sources: Germany (West und total): Jaeger et al. (2001), Komlos and Kriwy (2003); Germany (East): Jaeger et al. (2001), Komlos and Kriwy (2003); Bavaria: Baten (1999), Baten and Murray (2000), Harbeck (1960); Württemberg: Twarog (1997); Palatinate: Baten (1999), Baten and Murray (2000); Northrhine-Westphalia: Blum (2011); (Blum, 2012). Average height is organized by birth date, reflecting socioeconomic conditions around birth since this is the most important period for the determination of final average adult height.

[21] Despite the existence of several estimates and approximations of the development of investment we stick to Krengel's (1958) data (Vonyó 2012, Scherner 2013).

Data in **infant mortality rates** are provided by Mitchell (2007) and measures the share number of infants (by 1000) who died within the first 12 months after birth.

Forestry: Germany had an established reputation as one of the most advanced nations involved in forestry management and inspired British and U.S. developments in silviculture (e.g. see Schlich (1904), Zon (1910), Hiley (1930), B.P.P. (1942-43), Heske (1938)). Information on German forestry stock was taken from 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 (#, 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: German carbon pollution estimates 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 WW2 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: Data on historical interest rates and government bond yields were taken from Homer and Sylla (2005) and Deutsche Bundesbank (2013)[22].

[22] Data download from http://www.bundesbank.de, accessed 23/9/2013

Table A1: Estimated parameter values for alternative measures of investment when future wellbeing is measured by the PV of consumption per capita over 20-100 years horizons, 3 per cent /year discount rate (incl. 1944-48)

Dependent variable	Independent variable	β1	Standard error	β0	Standard error	N	β1=1	β0=0; & β1=1	ADF	R²	Sample
PV Cons. 20	Net	1.286***	(0.157)	542.3**	(249.6)	140	3.32*	13.15***	-2.289	0.328	1850-1989
PV Cons. 30		1.427***	(0.219)	937.9***	(315.9)	130	3.81*	19.07***	-1.723	0.25	1850-1979
PV Cons. 50		0.0601	(0.379)	2,353***	(395.5)	110	6.16**	19.12***	0.442	0	1850-1959
PV Cons. 100		0.839***	(0.124)	705.3***	(82.48)	60	1.67	154.27***	-2.970**	0.44	1850-1909
PV Cons. 20	Green	1.265***	(0.168)	711.1***	(248.3)	140	2.50	15.28***	-2.192	0.292	1850-1989
PV Cons. 30		1.393***	(0.235)	1,125***	(313.2)	130	2.80*	20.59***	-1.611	0.216	1850-1979
PV Cons. 50		-0.23	(0.396)	2,525***	(379.6)	110	9.63**	22.68***	1.533	0.003	1850-1959
PV Cons. 100		0.894***	(0.144)	715.9***	(87.21)	60	0.55	167.34***	-2.877**	0.401	1850-1909
PV Cons. 20	GS	1.114***	(0.11)	452.7**	(223)	140	1.07	7.27**	-2.206	0.427	1850-1989
PV Cons. 30		1.320***	(0.172)	840.9***	(295)	130	3.47*	16.55***	-1.753	0.316	1850-1979
PV Cons. 50		0.0596	(0.384)	2,352***	(404.9)	110	6.00**	18.51***	0.545	0	1850-1959
PV Cons. 100		0.815***	(0.122)	701.6***	(83.53)	60	2.31	142.57***	-2.968**	0.437	1850-1909
PV Cons. 20	GScarbon	1.125***	(0.113)	465.2**	(224.5)	140	1.23	7.81***	-2.205	0.419	1850-1989
PV Cons. 30		1.325***	(0.176)	859.9***	(296.6)	130	3.43*	16.82***	-1.744	0.308	1850-1979
PV Cons. 50		0.0155	(0.386)	2,383***	(403.6)	110	6.50**	18.93***	1.354	0	1850-1959
PV Cons. 100		0.819***	(0.123)	701.5***	(83.94)	60	2.18	143.20***	-2.959**	0.434	1850-1909
PV Cons. 20	GreenTFP	0.591***	(0.0377)	-491.2**	(205.2)	139	117.73***	199.30***	-2.547	0.643	1851-1989
PV Cons. 30		0.793***	(0.0544)	-546.3**	(258.2)	129	14.47***	38.63***	-2.424	0.626	1851-1979
PV Cons. 50		1.079***	(0.122)	-413.3	(394.7)	109	0.43	0.60	-2.299	0.424	1851-1959
PV Cons. 100		0.395***	(0.0483)	653.5***	(76.23)	59	157.29***	105.99***	-3.307**	0.54	1851-1909
PV Cons. 20	GSTFP	0.524***	(0.0329)	-402.8**	(198.4)	139	209.60***	300.03***	-2.361	0.649	1851-1989
PV Cons. 30		0.715***	(0.0492)	-451.5*	(253.7)	129	33.51***	62.07***	-2.200	0.625	1851-1979
PV Cons. 50		1.052***	(0.117)	-470.9	(395.2)	109	0.20	1.10	-2.289	0.431	1851-1959

PV Cons. 100		0.372***	(0.0452)	659.8***	(75.12)	59	192.95***	144.52***	-3.314**	0.543	1851-1909

Note: Discount rate of 3 per cent per anno was chosen on the basis of average real growth rate of the German economy during the period under observation. Also see table 1 for notes. See also table 1.

Table A2: Estimated parameter values for alternative measures of investment when future wellbeing is measured by the PV of consumption per capita over 20-100 years horizons, 3 per cent /year discount rate <u>(excl. 1944-48)</u>

Dependent variable	**Independent variable**	**β1**	**Standard error**	**β0**	**Standard error**	**N**	**β1=1**	**β0=0; & β1=1**	**ADF**	**R^2**	**Sample**
PV Cons. 20	Net	2.157***	(0.14)	-718.1***	(216.1)	135	68.38***	47.13***	-3.169**	0.641	1850-1989
PV Cons. 30		2.880***	(0.183)	-934.3***	(252.8)	125	105.44***	78.12***	-3.382**	0.668	1850-1979
PV Cons. 50		3.365***	(0.514)	-494.6	(467.3)	105	21.13***	25.41***	-2.427	0.293	1850-1959
PV Cons. 100		0.839***	(0.124)	705.3***	(82.48)	60	1.67	154.27***	-2.970**	0.44	1850-1909
PV Cons. 20	Green	2.212***	(0.156)	-525.5**	(221.9)	135	60.15***	46.05***	-3.075**	0.601	1850-1989
PV Cons. 30		3.026***	(0.207)	-754.3***	(259.7)	125	95.83***	75.90***	-3.418**	0.635	1850-1979
PV Cons. 50		3.328***	(0.622)	-152.6	(494.7)	105	14.03***	22.38***	-2.313	0.218	1850-1959
PV Cons. 100		0.894***	(0.144)	715.9***	(87.21)	60	0.55	167.34***	-2.877**	0.401	1850-1909
PV Cons. 20	GS	1.525***	(0.0956)	-346.0*	(192.2)	135	30.17***	20.33***	-2.720*	0.657	1850-1989
PV Cons. 30		2.132***	(0.144)	-451.1*	(241.1)	125	61.93***	48.36***	-2.905**	0.641	1850-1979
PV Cons. 50		3.294***	(0.521)	-525.2	(484.6)	105	19.38***	23.68***	-2.565	0.28	1850-1959
PV Cons. 100		0.815***	(0.122)	701.6***	(83.53)	60	2.31	142.57***	-2.968**	0.437	1850-1909
PV Cons. 20	GScarbon	1.556***	(0.0984)	-352.7*	(193.9)	135	31.99***	21.81***	-2.733*	0.653	1850-1989
PV Cons. 30		2.171***	(0.148)	-459.2*	(243.1)	125	62.93***	49.37***	-2.926**	0.638	1850-1979
PV Cons. 50		3.281***	(0.534)	-484.6	(490.5)	105	18.22***	23.07***	-2.536	0.268	1850-1959
PV Cons. 100		0.819***	(0.123)	701.5***	(83.94)	60	2.18	143.20***	-2.959 **	0.434	1850-1909
PV Cons. 20	GreenTFP	0.636***	(0.0337)	-807.0***	(185.8)	134	116.57***	261.21***	-2.417	0.729	1851-1989
PV Cons. 30		0.871***	(0.0443)	-1,038***	(212.5)	124	8.46***	69.13***	-2.678*	0.76	1851-1979
PV Cons. 50		1.303***	(0.0928)	-1,332***	(300)	104	10.65***	10.08***	-2.916**	0.659	1851-1959
PV Cons. 100		0.395***	(0.0483)	653.5***	(76.23)	59	157.29***	105.99***	-3.307 **	0.54	1851-1909

PV Cons. 20	GSTFP	0.558***	(0.0296)	-687.1***	(181)	134	222.08***	383.86***	-2.455	0.729	1851-1989
PV Cons. 30		0.778***	(0.0407)	-898.4***	(212.5)	124	29.76***	100.98***	-2.612*	0.749	1851-1979
PV Cons. 50		1.253***	(0.0894)	-1,351***	(301.8)	104	7.98***	11.14***	-2.979**	0.658	1851-1959
PV Cons. 100		0.372***	(0.0452)	659.8***	(75.12)	59	192.95***	144.52***	-3.314**	0.543	1851-1909

Note: Discount rate of 3 per cent per anno was chosen on the basis of average real growth rate of the German economy during the period under observation. Also see table 1 for notes. See also table 1.