XIV International Economic History Congress, Helsinki 2006
Session 52

Understanding Long Run Income Comparisons

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Summary
Using high quality data from the International Comparison Project (ICP), we develop empirical regularities for long run income measures. Typically, economists compare GDP by taking a recent purchasing power parity (PPP) adjusted GDP benchmark and projecting it backwards in time with domestic growth rates. Projections thus compare income over very long spans using the relative prices from a recent year. Our results show that such long run GDP estimates systematically understate income differences for the past. These differences are large and economically important and they are relevant to important debates.

Draft 1, Very Preliminary.
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May 30, 2006

1. Introduction

To compare GDP across countries, we have to adjust for differences in price levels. The modern literature on income comparisons begins in the 1950's with the path breaking work of the OEEC. Overseen by Milton Gilbert and Irving Kravis (Gilbert and Kravis (1954, 1958), the OEEC compared price levels and income for 1950 and 1955 for nine developed economies. The next step forward is with the International Comparison Project (ICP) created by Irving Kravis, Alan Heston and Robert Summers at the University of Pennsylvania. The ICP refined the OEEC methodology and extended it to virtually all economies.

Most economists know the ICP through the Penn Tables and the work of Angus Maddison. The Penn Tables provide comparable data on important national account aggregates for virtually all economies after 1960. Maddison (1995, 2001 and 2003) provides purchasing power parity adjusted income per capita for the leading economies over the very long run. The Penn Tables and Maddison rely on the post-1970 income benchmarks of the ICP. In simple terms, they compare GDP by taking one purchasing power parity (PPP) adjusted GDP benchmark and project it backwards in time with domestic growth rates.

This paper re-examines such long run income comparisons. We focus on the fact that projections compare income over very long spans using the prices of a recent year. Using high quality data from the International Comparison Project (ICP), we develop empirical regularities for long run income comparisons. Our results show that current long run GDP estimates systematically understate income differences for the past. These differences are large and economically important and they are relevant to important debates in economics.

We proceed as follows. Section 2 outlines how long run income comparisons work. Section 3 uses high quality data from the OEEC/ICP to develop the relationship between various income measures. Our results show that the projection approach used by Maddison (1995, 2001 and 2005) and others systematically understate income differences for years before the projection year and overstate income differences after. These differences are large and have implications for important debates. Section 4 shows that our findings are consistent with standard theory. As it turns out, there is a strong theoretical presumption that late period prices will understate income differences for early years.

Section 5 shows how to reconcile income estimates from different methodologies by taking into account changes in relative prices. We apply this method to various UK/US income comparisons from 1950 to 1996. The results suggest that shifts in relative prices explain a large proportion of the differences across estimates. Section six concludes by considering the implications of our findings for the central issues faced in long run income comparisons.

2. Projections and Current Price Benchmark Comparisons

This section provides background on long run income comparisons. We focus on the work of Angus Maddison (1995, 2001, and 2003) as his estimates are the most widely used.[1] Our results hold, however, for all long run comparisons that use late period base years.

We can illustrate the problems faced by long run income comparisons with the following example. Suppose, we wish to compare GDP per capita for two economies, say the US and the UK, for a year, say 1870, in the past. Maddison (1995, 2001 and 2003) does this as follows. He begins by forming a benchmark real GDP comparison for 1990 using equation (1) where $y_{i,1990,}$ is the real GDP for country *i* relative to the US in 1990 prices expressed in dollars, $Y_{i,1990}$ is the dollar denominated relative nominal GDP and $p_{i,1990}$ is the price level of country *i* measured in 1990 world prices obtained from the International Comparison Project (ICP).

(1) $$y_{i,1990} = Y_{i,1990}/p_{i,1990}$$

Equation (1) is Maddison's current price GDP benchmark. To generate comparative GDP for other years, he projects the GDP benchmark backwards and forwards with GDP growth rates in domestic prices. Equation (2) is the projection for year T where g_i is the growth rate between the benchmark year and year T, and $\overline{y}_{i,T}$ is the projected GDP series for country *i* at year T in terms of the US.

[1] Previous editions of his estimates are in Maddison (1964, 1969, 1982, 1983 and 1991). Colin Clark (1940, 1957) developed the projection approach. Other long run income comparisons using projections include Bairoch (1976), Crafts (1983), DeLong (1988) and Baier, Dwyer and Tamura (2006). Baier, Dwyer and Tamura (2006) also provide GDP per worker as well as estimates of human and physical capital stocks.

(2) $\overline{y}_{i,T} = (1+g_i)/(1+g_{us}) \cdot y_{i,1990}$

The projections are in 1990 "world prices".[2] There are two potential problems with projections. Using our example, projections compare 1870 income with 1990 prices. Relative prices differ greatly across these periods. How does this affect the comparison? In general, the literature is silent on this question. The second problem is that economies calculate growth rates differently thereby potentially distorting the comparisons.

Such concerns led to the development of current price historical GDP comparisons. Equation (3) compares income in current prices for 1870. Here $Y_{i,1870}$ is relative nominal income in dollars where $p_{i,1870}$ is the historical price benchmark constructed from disaggregated price and expenditure data for 1870.

(3) $y_{i,1870} = Y_{i,1870}/p_{i,1870}$

The recent literature on historical price benchmarks starts with Heston and Summers (1980) on India/US.[3] Haig (1989) and Thomas (1995) consider Australia and the UK. Recent years have seen an upsurge with, amongst others, Ward and Devereux (2003, 2005) for the US/UK, Van Zanden (2003) for Java/Netherlands and Ma, Fukao and Yuan (2003) for China/Korea/Taiwan/US.[4]

[2] The Maddison series have the same growth rates as the domestic GDP series. This is not the case for the Penn Tables where growth rates are in world prices see Nuxoll (1994).

[3] Prados de la Escosura (2000) provides current price comparisons using a short cut regression method.

[4] The new approaches are controversial in some quarters see Broadberry (2003) and the reply by Ward and Devereux (2004).

How do these current price comparisons relate to long run projections? We shall approach this question in two ways. First, we determine the relationship empirically using high quality data from the ICP/OEEC. For these studies, we find overwhelming evidence that differences between the measures are large, are systematic in nature and are economically important. Second, we use index number theory to consider the theoretical relationship between projections and benchmarks.

3. Projections and Benchmarks: The Evidence

This section uses the OEEC/ICP studies to study the relationship between the Maddison projections and current price GDP benchmarks. We confine our attention to developed economies.[5] Throughout, the US is the base country.

We compare income per capita in current prices using equation (3). This requires an estimate of relative prices and nominal income. To compare price levels, we use Fisher ideal price indices from the OEEC and ICP studies. We choose the Fisher Ideal, as it is the standard bilateral measure. Later we shall see that this measure is, in a fundamental sense, close to the best measure available. Nominal income is from the Penn Tables.[6]

Table 1 gives the ratio of the Maddison projections of GDP per capita in 1990 prices to the current price benchmarks from OEEC/ICP.

[5] Developing economies lead to a different set of issues. We omit Germany as re-unification complicates the German case.

[6] By using recent data on nominal GDP, we follow Kravis (1976) and Maddison (1995). This means that our estimates differ from the original ICP income benchmarks. For the most part, the differences are small.

Table 1 Comparing GDP per capita in Current and 1990 Prices

US = 100

OEEC/ICP Round		Ratio of Maddison estimates in 1990 prices to Current Price Benchmark Estimates		
Year	Number of Countries	Average	Maximum	Minimum
1950	8	1.26	1.42	0.95
1955	8	1.25	1.39	0.95
1970	7	1.14	1.18	1.08
1973	7	1.14	1.21	1.06
1975	11	1.05	1.13	0.95
1980	14	1.03	1.22	0.93
1985	19	1.13	1.26	0.98
1990	20	1.02	1.09	0.98
1996	20	1.00	1.08	0.95
2002	21	0.93	1.00	0.86

Notes: *Fisher Ideal Indices*: 1950 and 1955 from Gilbert and Kravis (1958), Table 5 page 30.
1970, 1973 and 1975 from Kravis, Heston and Summers (1978 and 1982). 1980, 1985 and 1990 from Maddison (1995) 1996 from Heston and Aten (2002) Table 2 page 31. 2002 from the OECD. The OECD estimates use EKS price level measures. This is a multilateral generalization of the Fisher Ideal. In practice, EKS and Fisher Ideal provide almost identical results.
GDP per capita 1990 prices from Maddison
Nominal GDP from Penn World Tables

The OEEC and ICP provide a large number of high quality current price benchmark GDP comparisons for the post-war era. The OEEC studies cover nine economies for 1950 and 1955. There are ICP rounds for 1967, 1970, 1973, 1975, 1980, 1985, 1990 and 1996. More recently, the OECD provides regular benchmarks. The second column in Table shows the number of countries covered per year.[7] Over time, the coverage of the ICP has increased. In terms of countries, however, coverage differs from year to year.

[7] We exclude 1967, as the number of countries is small.

The central point that emerges from Table 1 is the systematic differences between projections in 1990 prices and current price benchmarks. For 1990, the slight differences reflect the fact that Maddison uses world prices while our benchmarks are Fisher Ideal indices. Before 1990, however, the Maddison projections overstate income relative to the current price benchmarks. Moreover, these differences increase over time. On average, the projections are fourteen percent higher in 1970. They are twenty-six percent higher in 1950.[8] In contrast, the projections understate income as we move forward in time. By 2002, they are ninety-three percent of the OECD current price benchmarks.

A comparison of the current price GDP per capita estimates with the Maddison projections for individual economies is also informative. It shows that differences between projections and current price measures are important in economic terms. Seven of the nine countries coved by OEEC for 1950 are in every round of the ICP. These are Belgium, France, Italy, Germany, the Netherlands, the UK and the US. Excluding Germany, we are left with six economies.

Table 2 compares the Maddison estimates of GDP per capita in 1990 prices with the current price estimates using a US base. In each case, the projections overstate relative income in 1950. They understate it in 2002. The differences are largest for Italy, the Netherlands and the UK. For all economies, projections show a weaker performance as compared to the current price benchmarks.

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[8] A puzzling feature of Table 1 are the 1985 results. These show lower income relative to the US than surrounding benchmarks. Summers and Heston (1991) suggest that the large appreciation of the US dollar may have influenced this round of the ICP see also Maddison (1995).

Table 2 Comparing GDP per Capita in Current and Constant 1990 Prices for Selected Economies

US = 100

Year	Maddison 1990 World Prices	Current Fisher Ideal Prices	Ratio	Maddison 1990 World Prices	Current Fisher Ideal Prices	Ratio
Belgium				***France***		
1950	57	47	1.21	55	48	1.15
1955	58	50	1.16	58	48	1.21
1970	71	65	1.09	78	70	1.11
1975	76	75	1.01	81	79	1.03
1980	78	79	0.99	81	79	1.03
1985	72	62	1.16	77	64	1.20
1990	74	74	1.00	78	75	1.04
1996	74	75	0.99	75	69	1.09
2002	75	82	0.91	76	77	0.99
Italy				***Netherlands***		
1950	37	26	1.42	63	44	1.43
1955	43	31	1.39	67	48	1.40
1970	65	55	1.18	80	69	1.16
1975	66	59	1.12	82	76	1.08
1980	71	70	1.01	79	72	1.10
1985	68	61	1.11	76	65	1.17
1990	70	70	1.00	74	73	1.01
1996	69	71	0.97	76	75	1.01
2002	68	76	0.89	77	87	0.89
UK						
1950	73	54	1.35			
1955	72	53	1.36			
1970	72	61	1.18			
1975	73	64	1.14			
1980	70	65	1.08			
1985	68	60	1.13			
1990	71	69	1.03			
1996	69	71	0.97			
2002	73	80	0.91			

Notes: See notes to Table 1.

Consider the UK/US. Maddison shows a constant UK/US income level from 1950 to 2002. For 1950 and 2002, UK income is seventy-three percent of US levels. The current price benchmarks show strikingly different trends. For 1950, UK income is fifty-four percent of US income. By 2002, it is eighty percent of US levels. The current price benchmarks and the projections therefore yield fundamentally different measures of relative performance.

We can summarize our result in terms of three empirical regularities. First, post-1950 data shows that projections do not equal current price benchmarks for developed economies.[9] This point is well-known in the international comparison literature. It is, unfortunately, almost unknown outside this literature.[10] The second two points are less well known. Second, differences between projections and benchmarks for developed economies are systematic. Projections understate income differences for periods before the benchmark year while they overstate income differences for years after the benchmark year.[11] As we shall see, standard economic theory predicts these outcomes. Third, differences between projections and current price benchmarks are economically important. For many countries, they change our understanding of relative economic performance.

[9] The fact that projections do not equal benchmarks means that implicit growth rates across the current price benchmarks do not equal the growth rates in the projections. Aten and Heston (2002) discuss this point.

[10] From the outset, the founders of the International Comparison project have emphasized that projections do not equal benchmarks see Kravis, Heston and Summers (1978, 1982), Heston and Summers (1993) and Aten and Heston (2002).

[11] The literature on reconciling projections and benchmarks does not mention the systematic nature of divergences between benchmark and projections. This is because work in this area focuses on differences between projections and benchmarks in world prices. These differences are not systematic.

4. Comparing Income over Time and Space

This section explains the findings in the previous section using the theoretical literature on international comparisons and a model adapted from Dowrick and Quiggen (1997) and Dowrick and Akmal (2005). [12] Assume there are two countries and that each produces two goods, steel and services. Steel is traded while services are not. We set the price of steel equal to the exchange rate. For standard Balassa Samuelson reasons, we assume that the price of services is higher for the richer economy.[13] Following the literature, we also assume that relative consumption is negatively related to relative prices.[14]

Figure 1 compares real income for these economies. A and B give output in the rich and poor economy respectively. [15] We assume the rich economy produces the same quantity of services but more traded goods. This ensures that its income is unambiguously higher. Following the convention in the literature, we take the rich economy as the base. We compare income with prices from the rich economy, with prices from the poor economy and with Fisher Ideal prices.

Comparing income with rich economy prices yields a relative income of oe/od. This is the *Laspeyres* measure of relative income. Using the poor economy prices yields a relative income of oc/ob. This is the *Paasche* measure. From Figure 1, rich economy prices yield a higher relative income. In other words, the *Laspeyres* measure of relative income exceeds the *Paasche*.

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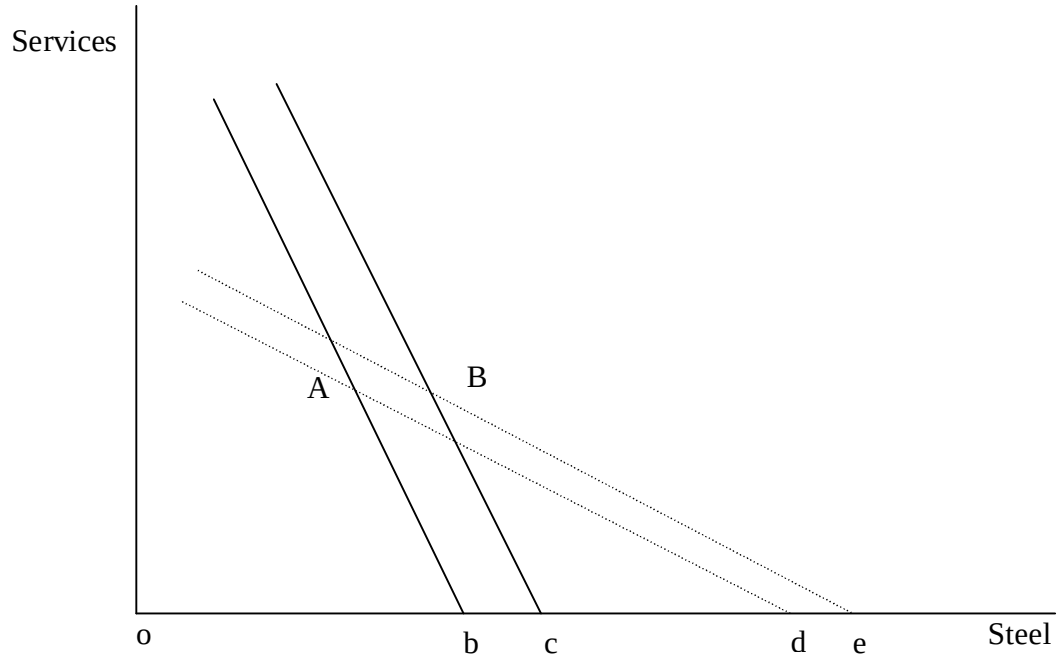
[12] Recent work includes Nuxoll (1994), Dowrick and Quiggen (1997), Dowrick and Akmal (2005), Hill (1999, 2004), and Neary (2004). Samuelson (1974) is a classic early contribution.

[13] The various round of the ICP show that nontraded prices increase with income. Bergin, Glick and Taylor (2004) find, however, that this relationship does not hold for earlier periods.

[14] There is overwhelming evidence from the ICP studies that this correlation holds in almost all cases.

[15] We provide a slightly more formal treatment in the appendix.

Figure 1 Comparing Income



The result is a general one and holds where prices and quantities are negatively related. It means that rich economy prices will overstate income relative to poor economy prices. The intuition is straightforward. Suppose we compare income for the US and India. Since traded prices are equal by assumption, using US prices raises the value of services that are consumed more in a relative sense in India. This raises Indian income.[16]

Next, we consider the Fisher Ideal index, the geometric average of the *Laspeyres* and *Paasche* measures. It yields a relative income intermediate between that obtained using the prices of the rich and poor economies.

[16] How large are the differences? The OEEC studies find that relative income at European prices is generally between seventy and eighty percent of income using US prices for the 1950's. For recent years, it is eighty to ninety percent of income using US prices. The narrowing of the spread is because relative prices have converged across developed economies. For poor economies, however, the *Paasche* can be less than one-half of the *Laspeyres* measure.

The problem with bilateral comparisons such as the Fisher Ideal is that they are not transitive. For this reason, the ICP relies on a multilateral comparison that compares income using "world prices" where world prices are measured using the Geary Khamis procedure. Crudely speaking, Geary Khamis prices are weighted averages of prices for all economies where weights are world expenditure shares.

A helpful way of looking at world prices is to assume that they represent the prices of a third, synthetic, country. This insight is due to Nuxoll (1994). His work, as confirmed by later research, showed that, in practice, world prices yielded by the Geary Khamis procedure are characteristic of developed economy.[17]

Earlier we noted that the Maddison projections use 1990 world prices to value income for the distant past. How does this choice influence the comparison? To answer this question, we avail of various results by Nuxoll (1994). His results refer to comparisons using world prices across space at a point in time. Fortunately, this is formally identical to comparing income over time. Consequently, we can apply his findings to interpret the effects of valuing income in the past using 1990 world prices.

For concreteness, assume we compare income in 1950 for the UK and the US with 1990 prices. Using our model, there are two possibilities. In the first case, the relative price of services for 1990 is higher than for either of the economies in 1950. Using world prices in these circumstances will raise the income of the poor economy relative to the *Laspeyres* measure for 1950. Referring back to Figure 1, this is shown by the fact that if we compare

[17] Dowrick and Ahmal (2005) find that world prices used in the Penn Tables approximate the relative price structure of Italy.

income using a higher relative price of services as compared to the rich economy in 1950 we get smaller income differences.[18]

The second case is where world relative price of services are lower in 1990 than for either economy. This corresponds to the case where we compare income for 2002 using 1990 prices. Here it is straightforward to show that world prices will overstate income differences relative to the *Paasche* measure. We show this in Figure 1 by taking a relative price of services lower than for the poorer economy.

These results go some way to rationalize the empirical findings from ICP/OEEC data. By using 1990 prices to value output for early years, we compare income with relative prices from a richer economy than the economies compared. This tends to understate income differences relative to the current price measure. On the other hand, using 1990 prices to compare income for later periods compares income with prices from a poorer economy. This will overstate income differences relative to the current price measure.

There is a final possibility. World prices can reverse income rankings. We consider this case in Figure 2. Here consumption of steel and haircuts are C and D respectively. The Fisher ideal measure shows equal incomes. Suppose that 1990 world prices show a higher relative price of services than the Fisher Ideal. This raises the income of the economy with more services and reverses income rankings as compared to the current price comparison.[19]

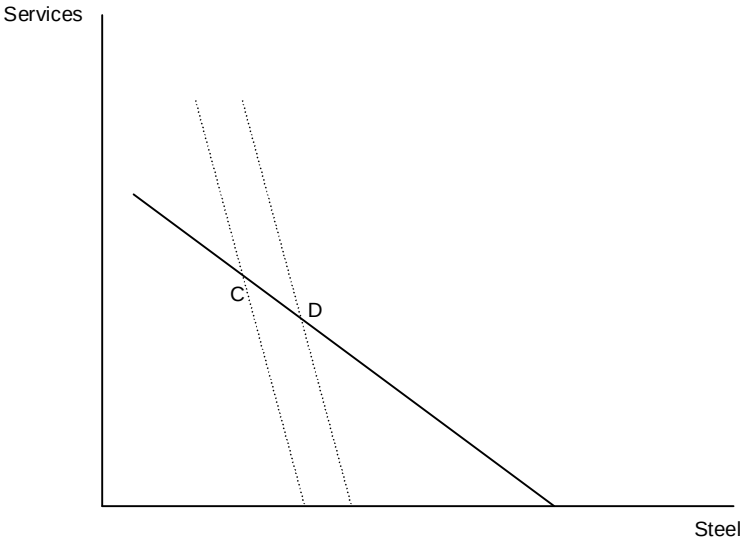
[18] Nuxoll (1994) provides a formal proof for comparisons across space. We can apply his results to comparisons across time

[19] This outcome can only occur when the output of services is higher in the economy with a lower income as measured by Fisher Ideal.

How important is outcome in practice? For post-1950 data, we found no case where 1990 prices reverse bilateral current price income rankings with the US.[20]

Figure 2

Comparing Income using World Prices



Which measure is preferred world or current prices? The answer depends on the question asked. There are important advantages associated with projections. Most obviously, they allow us to compare income for the years before 1950 where current price benchmarks do not exist. Second, projections preserve the growth rates of the domestic GDP series.[21] On the other hand, the theoretical literature is unanimous on one point. The Fisher Ideal index is preferred to world prices measures when comparing living standards or productivity for any two economies at a point in time. There seems to be complete agreement on this point see

[20] There are cases for the late nineteenth century where this appears to be the case. For 1870, Maddison shows that Belgium, the UK and the Netherlands have higher income per capita than the US. The current price benchmarks of Ward and Devereux (2002) shows the US ahead.

[21] On this point, see Kravis and Lipsey (1991). There are other advantages to world prices most notably "matrix consistency" since they allow adding up across countries and time. This property does not hold for Fisher Ideal measures.

Neary (2004). In the terminology of Diewert (1976), the Fisher ideal is a "superlative" index.[22] Diewert (1993) goes further and argues that the Fisher is the best among superlative indices. Thus, there is a powerful presumption in favor of the current price Fisher ideal measures over world price measures when we compare income across two countries at a point in time.

4. Can we Reconcile Projections and Current Price Benchmarks?

As we have seen, standard theory predicts that projections will understate income differences before the projection base year and overstate income differences after it. As we have seen, these predictions are consistent with the empirical evidence from the ICP/OEEC studies. This section provides a simple reconciliation of projections and current price comparisons. We are interested in reconciling GDP comparisons for two reasons. First, to be confident that differences between projections and benchmarks are, in fact, due to changes in relative prices we have to be able to reconcile various estimates. Second, by adjusting projections for changes in relative prices the reconciliation procedure can potentially improve projections.

Our task is to reconcile the projections in 1990 prices for year T (Y^T) with the current price income comparison (y^T_F) for this year. The appendix shows that the following relationship holds between the projection and the current price benchmark.

$$(4) \qquad Y^T/y^T_F = ((1+g)/(1+g_w))((1+G_w)/(1+G))Y^T_w/y^T_F$$

[22] In simple terms, a superlative index number is one that provides a second order approximation to the true index for a large class of preference specifications see Diewert (1976). Other superlative indices include the Tornquist and the Walsh. Neary (2004) emphasizes the importance of superlative indices for international comparisons.

In (4), g and G are growth rates in domestic prices and g_w and G_w are growth rates in world prices while (Y^T_w) is relative income for period T measured in world prices of year t.

Equation (4) shows that two factors explain differences between current price benchmarks and projections. The first is differences between growth rates calculated in domestic and world prices. We call this the growth rate effect. As shown in the appendix, the sign of this effect is uncertain. The second factor is the difference between relative income for year T evaluated at current year prices and relative income for year T evaluated at world prices of the projection year. This is the level effect considered in the previous section.[23] As we have seen, this effect reduces income differences for years prior to the base year and increases them for years after the base year.

To show how the reconciliation works, consider the UK/US case. We provide a complete account in the appendix. Column two in Table 3 gives the Maddison projections of UK/US GDP in 1990 prices. The first task is to determine the growth effect. To do this, we calculate growth for each economy using 1990 world prices and compare it to growth rates in domestic prices. There are three steps. First, we disaggregate GDP. Second, we form base weights in 1990 world prices. Finally, we calculate GDP using 1990 world prices. We can calculate growth rates in world prices from the expenditure or output side. We used the output side, as more disaggregation was possible. We have UK/US output indices for ten sectors, agriculture, mining, manufacturing, public utilities, construction, wholesale and retail trade, transport and

[23] We borrow these terms from Nuxoll (1994) who provides a related decomposition for the Penn World Tables.

communications, finance insurance and real estate, community social and personal services and government services.

Table 3

Reconciling Projections and Current Price Estimates of UK/US Income Per Capita

Year	Maddison Projections in Domestic prices	Maddison Projections in 1990 world prices	GDP Revalued Current Prices	Expenditure Benchmarks Current Prices
1950	73	73	49	54
1955	72	70	49	53
1967	70	68	55	59
1970	72	71	65	61
1973	72	69	63	59
1975	73	69	69	64
1980	70	67	63	65
1985	68	67	62	60
1990	71	71	70	69
1996	69	70	70	71

The projections in world prices are in column three. There is no systematic difference with Maddison who projects in domestic prices. We conclude that the growth effect plays a minor role in explaining differences between benchmarks and the projections for the UK/US.[24]

The next step is to adjust the projections for changes in relative prices. We outline the method in the appendix. The results are in column four. By comparing the projections in constant 1990 world prices with the projections that adjust for changes in relative prices, we obtain a measure of the level effect. Adjusting the projections for

[24] Nuxoll (1994) reaches a similar conclusion for the Penn Tables.

relative price change reduces UK/US income for each year. This effect increases over time. By 1950, UK/US income falls from seventy-one in 1990 prices to fifty adjusted to current prices.

The results show that late period price understate income differences in earlier periods. They also support the notion that differences in UK/US projections and income comparisons in current prices and constant 1990 prices are largely due to changes in relative price levels.

The final column provides the current price ICP expenditure benchmarks. For all years, the projections adjusted for changes in relative prices are reasonably close to the ICP benchmarks. This suggests that adjusting projections for changes in relative prices can potentially improve projections. However, some differences between the projections and the current price estimates remain. Such differences are to be expected. As explained at greater length in the appendix, our procedure allows for changes in relative prices across sectors. It does not adjust for changing relative prices within sectors. In addition, there are other factors explaining differences across projections and benchmarks that we ignore. Finally, expenditure and sectoral GDP comparisons are conceptually different and will never exactly coincide.

5. Concluding Comments

Using high quality post 1950 data from the OEEC and the ICP, we show that there are large differences between income comparisons based on projections from a single base year and income comparisons in current prices. These differences are systematic, as projections tend to understate income differences for years before the benchmark year and overstate income differences after the benchmark. Finally, we have argued that these patterns are consistent with standard economic theory.

What are the implications of these results for long run income comparisons? As we see it, the message of our results is that projections can provide misleading measures of relative living standards. This suggests that efforts devoted to pre-1950 historical GDP benchmarks are a worthwhile investment. On the other hand, we are unlikely to have current price benchmarks for all countries or for all periods. At a minimum, therefore, researchers who use long run projections need to be aware of the properties of their data. In particular, they need to be aware that projections tend to underestimate income differences in the past.

Our results show that long run income comparisons face difficult obstacles. We see, however, little reason for pessimism. In the first place, the projections of the Penn Tables and Maddison have greatly increased our knowledge of growth and living standards. Even without current price benchmarks, we possess powerful crosschecks of long run projections. First, we can adjust the projections for changes in relative prices. As shown in the appendix, all this requires is disaggregated GDP in current and constant prices. Second, we have the short-cut procedure developed by Prados de la Escosura (2000) that provides relative GDP in current prices. Finally, real wages act as a cross

check. Heston (1998) argues that real wages and relative output per worker are closely connected.[25] Used properly, projections, current price benchmarks, real wages and short cut comparisons provide a powerful set to tools with which to study modern economic growth.[26]

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[25] The relationship is given by $w_{i/us} = \underline{y}_{i/us}(\beta_i/\beta_{us})(p/p_c)$ where $w_{i/us}$ are relative real wages in terms of the US, $\underline{y}_{i/us}$ is relative output per worker, β the share of labor income in GDP and p/p_c is the relative GDP deflator level divided by the relative consumption price level. With the exception of the UK, the scattered evidence provides little evidence that labor shares differ developed across economies in a systematic fashion see Prados De La Escosura and Roses (2003).

[26] Ward and Devereux (2005) use current price benchmarks, projections, short cut estimates, real wages and data on sectoral productivity to study relative UK/US GDP for the early and middle nineteenth century.

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Appendix One

This section establishes the relationship between projections and current price benchmarks. For simplicity, we consider two periods, t and T. Let us identify our economies by the subscripts i and j where i is the base economy. Suppose that we have comparable data on prices and quantities for period t. Equation (1) compares income using prices of the base country where y^t_i is relative income and $\mathbf{P^t}$ is a vector of prices in the base economy while $\mathbf{X^t}$ and and $\mathbf{x^t}$ are quantities in the base country and partner country. Equation (1) is the *Laspeyres* measure.

$$(1) \qquad y^t_i = (\mathbf{P^t x^t})/(\mathbf{P^t X^t})$$

We can also compare GDP using prices of the poor economy yielding the *Paasche* measure in (2) where $\mathbf{p^t}$ are prices in the partner country.

$$(2) \qquad y^t_j = (\mathbf{p^t x^t})/(\mathbf{p^t X^t})$$

Assuming that quantities are negatively related to prices, it easy to show that (1) will show a higher level of income as compared to (2).

The Fisher Ideal measure is the geometric average of (1) and (2).

$$(3) \qquad y^t_F = (y^t_i \, y^t_j)^{0.5}$$

The Penn Tables and Maddison compare income using world prices. This measure is equation (4) where **P** is the vector of world prices in year t.

(4) $$y^t_W = (\mathbf{P}\mathbf{x}^t)/(\mathbf{P}\mathbf{X}^t)$$

Suppose now we want to compare income for these countries for some period T in the past. Maddison (1995, 2001 and 2003) projects (4) with domestic growth rates. Equation (5) gives the projection for time T where Y^T is the projection of income for the first period and g and G are the growth rates of the partner and base economy respectively.

(5) $$Y^T = y^t_W(1+g)/(1+G)$$

In this simple example, there are three ways to calculate growth rates for each economy. Take the rich economy. We could calculate growth rates using first year prices, using second period prices or we could take a chained index. These options also exist for the partner economy. In all, there are nine ways to form projections. This reflects the fundamental problem that projections are not unique. The sign of the growth rate is thus uncertain.

The second problem with projections is that conceptually is difficult to interpret the results. There is one exception. The Penn Tables projects its benchmarks using growth rates calculated in world prices. Using (4) and (5) and simplifying we obtain (6).

(6) $$Y^{T}_{w} = y^{t}_{W}(1+g_w)/(1+G_w) = (\mathbf{P}\mathbf{x}^{\mathbf{T}})/(\mathbf{P}\mathbf{X}^{\mathbf{T}})$$

With world prices, the projections are unique. Moreover, the projections have a clear interpretation. From (6), the projection is equivalent to comparing income for period T using world prices from period t.

Using (6), we can establish the relationship between projections and current price benchmarks for any year.

(7) $$Y^{T}/y^{T}_{F} = ((1+g)/(1+g_w))((1+G_w)/(1+G))Y_w/y^{T}_{F}$$

This is given as (4) in the text.