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Trading gains: New Estimates of Swiss GDP, 1851 to 2008

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Abstract

This paper revises Swiss GDP emphasizing the difference between single and double deflation, which depends on trading gains: i.e. gains from terms of trade and from the real exchange rate. These gains contributed significantly to Swiss economic growth between 1930 and 1990. Earlier series of Swiss GDP have neglected trading gains. In backward projections, this leads to overestimation of GDP (per capita) levels. The Maddison database (Bolt & Zanden 2014), for example, suggests that Swiss GDP per capita was 38 percent above that of the USA in 1875. My series shows that Swiss GDP per capita was still below the Western European average.

Keywords: Historical National Accounts, Gross Domestic Income, Double deflation, Real Exchange Rate, Terms of Trade, Switzerland
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1. Introduction

This paper emphasizes the difference between single- and double-deflated GDP series. Double-deflated GDP holds all prices constant including the relative price structure. Thereby it excludes gains or losses from relative price changes such as the terms of trade or the real exchange rate. Thus the growth rate of double-deflated GDP contains only increases due to factor accumulation and productivity growth. Single-deflated GDP holds only the general price level constant but allows for relative price changes. Thereby it includes also trading gains arising from changes in the terms of trade and the real exchange rate.

The national accounting literature in the 1960s was aware of this methodological problem and has debated different deflators to measure trading gains (Nicholson 1960; Geary 1961; Bjerke 1968; David 1962; David 1966; Hansen 1974). But no conclusion was reached so that the System of national accounts defined double deflation as the standard procedure (SNA 1968). Diewert and Morrison (1986), however, show that improvements in terms of trade have the same impact on aggregate welfare as technological progress. They provide a methodology to adjust output and productivity indexes to include these gains. In a similar vein, Kohli (2004) argues that trading gains from terms of trade and from the real exchange rate are real effects that should be included in any measure of income and welfare. The Penn world tables now also propose measures of GDP per capita that include trading gains (Feenstra et al. 2015).

Historians have not paid enough attention to the difference between double and single deflation using the two types of estimates interchangeably. Obviously, the choice of an accurate measure depends on the conceptual focus. If the focus is on living standards, welfare or command over resources, single-deflated GDP per capita is more adequate. For a focus on productive capacity, a double-deflated series should be used. Whenever, relative price changes are important the distinction between the two deflation methods is important.

A similar methodological problem arises with international comparisons of GDP (per capita) levels. Instead of using market exchange rates, such comparisons use purchasing power parities

(PPP), which take account of the diverging price levels of different economies (Deaton & Heston 2010). PPP-adjusted GDP estimates can also include or exclude terms of trade and real exchange rate effects (Feenstra, Heston, et al. 2009; Feenstra et al. 2015, p.3170).

The estimation of reliable purchasing power parities (PPP) is extremely data intensive and methodologically complicated. The International Comparisons Program has carried out this exercise only 7 times since 1970. For years, other than those benchmark periods, PPPs are extrapolated using price index numbers from national accounts statistics. Logically, benchmarks which include terms of trade and real exchange rate effects should be extrapolated with deflators that account for these effects and vice versa (Feenstra, Heston, et al. 2009).

In historical research the limited availability of price data has lead to a wide spread use of time-series projections. The famous Maddison database, which extrapolates GDP per capita levels backwards from a 1990 PPP benchmark, is certainly the most widely used dataset on historical GDP per capita in the history and the economics literature. It continues to be extended and updated with new estimates (Maddison 1995; Maddison 2003; Maddison 2008; Bolt & Zanden 2014; Fouquet & Broadberry 2015). The 1990 Maddison benchmark includes trading gains. Therefore, extrapolations from this benchmark should rely on single-deflated GDP per capita series, which also take account of these effects.

Switzerland is the perfect showcase for the difference between single and double deflation. As I will show in this paper, important changes of relative prices have occurred in this country between 1930 and 1990. The appreciation of the real exchange rate and the improvement of terms of trade have given way to significant gains, which single deflation accounts for while double deflation does not. Hence, gains from relative price changes drive an enormous wedge between single- and double-deflated GDP series. Existing long-run series of Swiss GDP confound single and double deflation and blur the interpretation of the Swiss growth trajectory.

The lack of distinction between the two deflation methods is particularly harmful in the context of international comparisons based on time series projections. Figure 1 illustrates Swiss GDP per capita from the Maddison database (Bolt & Zanden 2014) in comparison to other Western

European countries and the USA. The extremely high GDP per capita level implied by this series is striking: already in 1890 Swiss GDP per capita was more than 20 percent above that of the UK and 40 percent above that of the USA keeping its huge advance until WWII. Three pieces of evidence stand against this: First, the older series from Maddison (2003) suggests much lower levels. Unfortunately, the long-term trend of this series relies on two implausible growth spurts at the end of the two world wars, in particular a 49% increase in GDP per capita between 1944 and 1947. Second, international comparisons from Prados de la Escosura (2000), imply that Switzerland was clearly behind the USA. Figure 1 shows alternative estimates of Swiss GDP per capita derived by combining the Switzerland/UK comparison from Prados de la Escosura with the Maddison UK series. Third, Roman Studer (2008) has shown that Swiss real wages were very low in international comparison until 1910. These low levels are hardly reconcilable with the extremely high GDP per capita level of the Maddison update.

Figure 1

In order to clarify our knowledge of the Swiss growth trajectory I provide new estimates of Swiss GDP and GDP per capita elaborating a coherent framework of national accounting measures. I compute GDP from the expenditure and the output approach, providing series in nominal as well as real terms, and distinguishing between single and double deflation. Finally, I provide a new time series projection of GDP per capita from the 1990 Maddison benchmark, which is based on single deflation. The main conclusion from this projection is that late 19th and early 20th-century Switzerland was much less rich than suggested by the Maddison database (Bolt & Zanden 2014).

Based on my theoretical discussion of deflation methods, I decompose the Swiss growth trajectory into increases of productive capacity, gains from the real exchange rate, and gains from terms of trade. As it turns out, growth before 1930 stemmed exclusively from factor accumulation and total factor productivity growth, while growth after 1930 included large trading gains, particularly from the appreciation of the real exchange rate. This suggests a distinction between two successive growth regimes of the Swiss economy.

The structure of the paper is as follows. Section 2 provides a theoretical discussion of GDP measurement and elaborates a complete national accounting framework including a decomposition into increased productive capacity, real exchange rate gains and terms of trade effects. Section 3 applies this framework to the Swiss economy from 1890 to 1990 and provides an historical explanation of relative price changes and trading gains. Section 4 interprets the Swiss growth trajectory in international comparison and identifies two distinct growth regimes.

2. Definitions and deflation procedures

In this section I discuss different concepts of GDP. Particular interest will be given to deflation methods. Double-deflation excludes gains from relative price changes, while single deflation includes them. In the spirit of Diewert and Morrison (1986) and Kohli (2004; 2006a; 2006b), I argue that gains from relative price changes have a real effect on the economy and should not simply be deflated away. Adapting the growth decomposition of Kohli to the context of historical national accounting, I propose a decomposition of trading gains, which is suitable for the Laspeyres quantity indexes used in Swiss national accounts until 1990. While Kohli's decomposition is limited to GDP by expenditure, I also propose a decomposition of relative price gains for value added by industry reporting the contribution of different industries.

GDP can be measured from the expenditure, the output, or the income approach. In this paper I focus on the first two. GDP by expenditure is defined as follows

$$Nominal\ GDP = PQ = KN + EX - IM \tag{1}$$

where K and N stand for domestic prices and quantities (including consumption, investment, and government expenditure), E and X denote export prices and quantities, and I and M are import prices and quantities. The index of nominal GDP of year t with respect to some base year 0 is

$$\Gamma_{t,0} = \frac{Nominal\ GDP_t}{Nominal\ GDP_0} = \frac{K_t N_t + E_t X_t - I_t M_t}{K_0 N_0 + E_0 X_0 - I_0 M_0} \tag{2}$$

GDP from the production approach is defined as the sum of value added of all industries

$$Nominal\ GDP = PQ = \sum_i^N P_i Q_i - p_i q_i \tag{3}$$

where P_i and Q_i stand for output prices and quantities of industry i and p_i and q_i are prices and quantities of intermediate goods used by industry i. The index of nominal value added is

$$\Gamma_{t,0} = \frac{Nominal\ VA_t}{Nominal\ VA_0} = \frac{\sum_i^N P_{i,t} Q_{i,t} - p_{i,t} q_{i,t}}{\sum_i^N P_{i,0} Q_{i,0} - p_{i,0} q_{i,0}} \tag{4}$$

Note that in both approaches, GDP is not an observed flow of goods but a residual.

2.1. Real GDP by expenditure

Today it is common practice to measure value added in constant prices with a double deflation procedure. This procedure consists of deflating each netput with its own price index. The advantage of this method is that every item is deflated by the closest corresponding price index. The System of National Accounts 1993 (SNA 1993) recommends this procedure and most statistical offices today follow this recommendation. Most countries measure real GDP indices using the Laspeyres formula, although a few countries have now adopted more sophisticated superlative index numbers. The Laspeyres index of real GDP by expenditure is

$$\mathrm{Q}_{t,0}^{L} = \frac{K_0 N_t + E_0 X_t - I_0 M_t}{K_0 N_0 + E_0 X_0 - I_0 M_0} = s_0^N \frac{N_t}{N_0} + s_0^X \frac{X_t}{X_0} - s_0^M \frac{M_t}{M_0} \tag{5}$$

with $$s_0^N = \frac{K_0 N_0}{K_0 N_0 + E_0 X_0 - I_0 M_0}$$

The last term of equation (5) decomposes the GDP index into the contributions of the domestic, the export, and the import sectors.

This is the standard double deflation method. Real GDP is a residual. Its price is not observed but results from addition and subtraction of deflated elements (an implicit price index). This deflation method does not only transpose the price level of the base year on year t but also its relative price structure. Thereby, it does not account for gains resulting from relative price changes. Ceteris paribus, an improvement of the terms of trade

$$T = E/I$$

e.g. a decline in import prices, increases the amount of goods available to the economy: more imports can be acquired for the same amount of exports. Paradoxically, the GDP deflator will increase, when import prices fall and real GDP will decrease. Unless the decrease in import prices is accompanied by an equivalent decrease in domestic prices, the real exchange rate

$$R = I/K$$

will also be altered in case of falling import prices. Substitution of imported goods for domestic goods will increase the amount of goods available. Hence, relative price changes have a real effect on the economy. Double-deflated GDP does not account for this effect and is therefore not an adequate measure of income and welfare (Kohli 2004).

2.2. Gross Domestic Income

The fact that double deflation excludes gains from terms of trade has given way to considerable debate. Measures of GDP that include trading gains are often labeled Gross Domestic Income (GDI). In nominal terms GDI is equivalent to GDP by expenditure. The difference between GDP and GDI therefore stems solely from the deflation procedure.

Early contributions to the debate have suggested deflation of the nominal trade balance rather than of exports and imports separately. Different deflators have been suggested such as import or export prices (Flexner 1959; Stuvel 1959; Nicholson 1960), an average of the two (Courbis 1969), import prices in case of a trade deficit and export prices in case of a trade surplus (Geary 1961), or domestic prices (Bjerke 1968). However, no consensus has been reached as to which deflator is best. The younger literature has shifted its focus from the choice of a particular deflator to the formulation of superlative index numbers derived directly from the aggregate production function. In a seminal paper, Diewert and Morrison (1986) have used the translog production function to show that the welfare effect of changes in terms of trade is equivalent to that of total factor productivity growth. Their demonstration relies on output and sales functions of the economy, which highlights that gains from relative prices affect not only consumers but also the production sector.

Kohli (2004) points out a pradoxical behavior of the GDP deflator: in a situation where everything remains unchanged with the exception of falling import prices, double-deflated GDP will actually decrease and the GDP deflator will increase. This paradoxical behavior stems from the fact that import prices enter the GDP deflator negatively. In order to solve the problem Kohli suggests deflation of all elements of nominal GDP with domestic prices. This yields a measure of GDI in units of domestic consumption (including investment and government expenditure). Surprisingly, Kohli argues that his measure of GDI is a measure of national production. However, his numéraire N and his deflator $K_{t,0}$ do not include exports, which are part of national production.

From a production point of view, it makes more sense to measure GDI in units of national production. But what is the price index of national production? Under the assumption that all imports go through the national production sector[1] *KN+EX* corresponds exactly to national production. Hence, domestic consumption and exports can be deflated with their own price and imports with the price index of aggregate demand *KN+EX*. Equivalently nominal GDP can be deflated directly with the price index of aggregate demand.

Equation (1) can be rearranged to equate aggregate supply and demand

$$PQ + IM = KN + EX$$
$$aggregate\ demand = KN + EX$$
$$aggregate\ supply = PQ + IM$$

The Laspeyres index of aggregate demand is

$$\mathrm{D}_{t,0}^{L} = \frac{K_0 N_t + E_0 X_t}{K_0 N_0 + E_0 X_0} = \frac{K_0 N_0 \frac{N_t}{N_0} + E_0 X_0 \frac{X_t}{X_0}}{K_0 N_0 + E_0 X_0} = d_0^N \frac{N_t}{N_0} + d_0^X \frac{X_t}{X_0} \tag{6}$$

with $d_0^N = \dfrac{K_0 N_0}{K_0 N_0 + E_0 X_0}$ $\qquad d_0^X = \dfrac{E_0 X_0}{K_0 N_0 + E_0 X_0}$

The deflator of aggregate demand takes the Paasche form

$$\mathrm{G}_{t,0}^{P} = \frac{K_t N_t + E_t X_t}{K_0 N_t + E_0 X_t} = \frac{K_0 N_t \frac{K_t}{K_o} + E_0 X_t \frac{E_t}{E_o}}{K_0 N_t + E_0 X_t} = \delta_t^N \frac{K_t}{K_0} + \delta_t^X \frac{E_t}{E_0} \tag{7}$$

with $$\delta_t^N = \frac{K_0 N_t}{K_0 N_t + E_0 X_t} \qquad \delta_t^X = \frac{E_0 X_t}{K_0 N_t + E_0 X_t}$$

Deflating nominal GDP with the deflator of aggregate demand yields the following intuitive result:

$$\mathrm{Y}_{t,0}^L = \frac{\Gamma_{t,0}}{\mathrm{G}_{t,0}^P} = \frac{K_t N_t + E_t X_t - I_t M_t}{K_t N_t + E_t X_t} \frac{K_0 N_0 + E_0 X_t}{K_0 N_0 + E_0 X_0 - I_0 M_0} = (1 - \mathrm{d}_t^M)\left(s_0^N \frac{N_t}{N_0} + s_0^E \frac{X_t}{X_0}\right) \tag{8}$$

with $$\mathrm{d}_t^M = \frac{I_t M_t}{K_t N_t + E_t X_t} = \frac{I_t M_t}{P_t Q_t + I_t M_t} \qquad \mathrm{d}_t^Q = \frac{P_t Q_t}{P_t Q_t + I_t M_t} = (1 - \mathrm{d}_t^M)$$

Deflated domestic expenditures and exports are the same as in real GDP (i.e. their evolution is measured in terms of quantities produced) but deflated imports differ. Imports and output are now measured by their current-price shares of deflated aggregate supply (i.e. they are measured in units of national prduction). In sum, equation (8) measures growth including trading gains in units of national production.

Trading gains can be measured by subtracting real GDP from GDI. As expected, trading gains depend on the real exchange rate and terms of trade:

$$\mathrm{Y}_{t,0}^L - \mathrm{Q}_{t,0}^L = s_0^M \frac{M_t}{M_0}\left(1 - d_t^N \frac{R_t}{R_0} - d_t^X \frac{T_0}{T_t}\right) \tag{9}$$

If the real exchange rate and terms of trade remain constant, the term in parentheses becomes zero and GDI is equal to GDP. Hence, GDI can be decomposed into three components

$$\mathrm{Y}_{t,0}^L = \mathrm{Q}_{t,0}^L + \mathrm{R}_{t,o} + \mathrm{T}_{t,o} \tag{10}$$

with $$\mathrm{Q}_{t,0}^L = s_0^N \frac{N_t}{N_0} + s_0^X \frac{X_t}{X_0} - s_0^M \frac{M_t}{M_0}$$

$$\mathrm{R}_{t,o} = s_0^M \frac{M_t}{M_0} d_t^N \left(1 - \frac{R_t}{R_0}\right) \qquad \mathrm{T}_{t,o} = s_0^M \frac{M_t}{M_0} d_t^X \left(1 - \frac{T_0}{T_t}\right)$$

The first term represents growth due to changes in the employment of production factors and total factor productivity growth, whereas the second and third terms measure the contribution of changes in the real exchange rate and terms of trade. As can be seen, the real exchange rate effect is an increasing function of the share of domestic expenditure in aggregate demand, while the terms of trade effect increases with openness (measured by the share of exports in aggregate demand).

2.3. Double-deflated value added

As in the case of GDP by expenditure, the standard procedure to deflate GDP from the production approach is based on double deflation, i.e. output value is deflated by output prices and input value is deflated by input prices. Hence, the Laspeyres index of real value added is

$$\begin{aligned} \mathrm{Q}_{t,0}^{L} &= \frac{\sum_i^N P_{i,0}Q_{i,t} - p_{i,0}q_{i,t}}{\sum_i^N P_{i,0}Q_{i,0} - p_{i,0}q_{i,0}} = \sum_i^N s_{i,0}\left(\frac{1}{w_{i,0}}\right)\left(\frac{Q_{i,t}}{Q_{i,0}}\right) - s_{i,0}\left(\frac{1-w_{i,0}}{w_{i,0}}\right)\left(\frac{q_{i,t}}{q_{i,0}}\right) \\ &= \sum_i^N s_{i,0}\left(\frac{\omega_{i,t}}{w_{i,0}}\right)\left(\frac{Q_{i,t}}{Q_{i,0}}\right) \end{aligned} \tag{11}$$

with $$w_{i,0} = \frac{P_{i,0}Q_{i,0} - p_{i,0}q_{i,0}}{P_{i,0}Q_{i,0}} \qquad \omega_{i,t} = \frac{P_{i,0}Q_{i,t} - p_{i,0}q_{i,t}}{P_{i,0}Q_{i,t}}$$

$$s_{i,0} = \frac{P_{i,0}Q_{i,0} - p_{i,0}q_{i,0}}{\sum_i^N P_{i,0}Q_{i,0} - p_{i,0}q_{i,0}}$$

2.4. Single-deflated value added

Double deflation of value added has also been criticized in different respects. Paul David (1962), for example, insisted on the fact that double deflation of value added can yield negative values even if value added in current prices is positive. This problem stems from the fact that real value added is measured as a residual when double deflation is used. Again, double deflation imposes not only the general price-level of the base year on other years but also the relative price structure. Negative real value added simply reveals that the precise output and intermediate consumption quantities of the observed year would not be economically viable if relative prices of the base year had prevailed. In a later paper, David (1966) has suggested to deflate value added of each industry by the price index of its output.

SNA 1993 proposes another solution, which is to use chain indices when double deflating value added. Relative prices and technology of consecutive years are supposed to be least divergent, so that biases should be minimized (SNA 1993, p.490). In fact, Christopher Sims (1969) has demonstrated that double deflation yields a Divisia index of value added if the production function is separable and the price index is continuously chained. However, in practice, time is not continuous and production functions might well be inseparable (e.g. one can imagine that the use of materials can be reduced by investing in capital).

Stefano Fenoaltea (1976) has criticized both double deflation and deflation by industry specific output prices. The problem with these industry-specific deflators is that they change the inter-industry value added ratios of all years except the base year. If observed current-price value added ratios between industries are right, then the ratios obtained from double-deflated or output-price deflated value added are wrong. Hence, according to Fenoaltea, current values added of different industries must be deflated by the same price index, e.g. a price index of a composite good such as a consumer price index.

In sum, single deflation is a way to achieve a measure of real value added that includes trading gains. It is also less affected by lacking quality of the price data (SNA 1993, p.491) and it allows for deflation of value added even if data on input prices is entirely lacking. Single deflation with a consumer price index is somewhat arbitrary because the underlying consumer basket is not necessarily representative for GDP, which contains also other goods than consumption goods, but it can be a reasonable choice if the focus is laid on income. Single deflation with output prices is more adequate when the focus lays on production, but it introduces distortions in relative value added of different industries. A possible solution is deflation in two steps: Deflation with output prices for the computation of aggregate value added in a first step and a subsequent industry wise deflation with the GDP deflator obtained from the first step. This procedure is well in line with historical national accounting, because in historical national accounting single deflation with output prices is a widely used procedure because of its weaker data requirements.

The Laspeyres index of single-deflated value added is

$$
\begin{aligned}
\mathrm{Y}_{t,0}^{L} = \frac{\sum_i^N P_{i,0}Q_{i,t} - P_{i,0}\dfrac{p_{i,t}}{P_{i,t}}q_{i,t}}{\sum_i^N P_{i,0}Q_{i,0} - p_{i,0}q_{i,0}} &= \sum\nolimits_i^N s_{i,0}\left(\frac{1}{w_{i,0}}\right)\left(\frac{Q_{i,t}}{Q_{i,0}}\right) - s_{i,0}\left(\frac{1-w_{i,0}}{w_{i,0}}\right)\left(\frac{q_{i,t}}{q_{i,0}}\right)\left(\frac{T_{i,0}}{T_{i,t}}\right) \\
&= \sum\nolimits_i^N s_{i,0}\left(\frac{w_{i,t}}{w_{i,0}}\right)\left(\frac{Q_{i,t}}{Q_{i,0}}\right)
\end{aligned} \tag{12}
$$

with $$\frac{T_{i,0}}{T_{i,t}} = \left(\frac{P_{i,0}}{p_{i,0}}\frac{p_{i,t}}{P_{i,t}}\right) \qquad w_{i,t} = \frac{P_{i,t}Q_{i,t} - p_{i,t}q_{i,t}}{P_{i,t}Q_{i,t}}$$

Hence, single-deflated value added is a positive function of industry terms of trade defined by the ratio of output to input prices of the industry. Note that, single-deflated value added corresponds to its current-price share of deflated gross output. Conceptually this is similar to GDI measured by domestic output's current-price share of deflated aggregate supply.

The difference between double-deflated and single-deflated value added yields a measure of trading gains, which corresponds to a weighted average of the terms of trade gains of all industries.

$$\mathrm{Y}_{t,0}^{L} - \mathrm{Q}_{t,0}^{L} = \sum\nolimits_{i}^{N} s_{i,0}\left(\frac{1-w_{i,0}}{w_{i,0}}\right)\left(\frac{q_{i,t}}{q_{i,0}}\right)\left(1-\frac{T_{i,0}}{T_{i,t}}\right) \tag{13}$$

Some industries will realize positive terms of trade gains while others will suffer losses. In a closed economy these gains and losses cancel out when industries are aggregated but in an open economy the sum of industry terms of trade gains will correspond to total trading gains of the economy.

As pointed out by Fenoaltea (1976), industry-specific deflators introduce important distortions in relative industry value added ratios. If trading gains are to be measured by industry, all industries' value added should be deflated with the same deflator. If the deflator of single-deflated value added is used industry value added including trading gains is

$$\mathrm{Y}_{i,t,0}^{L} = \frac{\Gamma_{i,t,0}}{\mathrm{G}_{t,0}^{P}} = L_{i,t,0}\left[\frac{1}{w_{i,0}}\frac{Q_{i,t}}{Q_{i,0}} - \frac{1-w_{i,0}}{w_{i,0}}\frac{q_{i,t}}{q_{i,0}}\frac{T_{i,0}}{T_{i,t}}\right] = w_{i,t}L_{i,t,0}\frac{1}{w_{i,0}}\frac{Q_{i,t}}{Q_{i,0}} \tag{14}$$

with $$L_{i,t,0} = \frac{P_{i,t}}{P_{i,0}}\sum\nolimits_{i}^{N} s_{i,t}\frac{P_{i,0}}{P_{i,t}}$$

The second term in square brackets shows industry terms of trade gains or losses, whereas $L_{i,t,0}$ is a measure of the output price level of the industry relative to the aggregate output price level. Hence, there are two types of gains from relative price changes: gains from falling prices of intermediate goods relative to output prices, and gains from rising output prices relative to output prices of all other industries. The last term in equation (14) shows again that single-deflated industry value added corresponds to the current-price share of deflated industry output.

2.5. International comparisons from time-series projections

Time-series projections from benchmark comparisons are a standard procedure. The International Comparisons Program has elaborated only seven benchmark comparisons since 1970. For all other years national price index numbers are used to extrapolate PPP levels from these benchmarks. However, such projections often turned out to be significantly different from the PPPs of the next benchmark round. Particularly large differences were found between extrapolations from the 2005 ICP benchmark and the 2011 direct estimate. The possible reasons for these differences have been widely discussed in the national accounting literature (McCarthy 2011; Feenstra et al. 2013; Deaton & Aten 2014; Inklaar & Rao 2016).

Methodological differences between the two benchmarks loom large. Constructing a new 2005 benchmark with the 2011 methodology, Inklaar and Rao (2016) reduce the mean difference between projections and the direct 2011 benchmark from 16.5 to 8.8 percent; and most importantly, they show that these reduced differences are not systematically related to expenditure per capita any more. However, the fact that a significant mean difference of more than 8 percent remains even if the benchmarks are methodologically consistent calls for additional explanation. Inconsistency between the benchmarks on the one hand and the time-series on the other is a possibility. Here the treatment of trading gains is of importance. As in the case of comparisons of GDP over time, comparisons in space can or cannot account for changes in relative prices. Until recently, ICP has not coherently distinguished between these two approaches. Benchmark PPP estimates relied only on domestic prices, so that GDP levels were compared taking the actual relative prices as given, while projections relied on the GDP deflator, which imposes the relative price structure of the base year on other years. That is, GDP benchmarks included gains from relative price changes, while the time-series used for projection did not. Feenstra et al. (2009) have criticized this inconsistency and suggested a clear distinction between GDP^E, which includes trading gains, and GDP^O, which does not. It is a matter of conceptual coherence that projections from a benchmark, which includes these gains, should be made with single-deflated GDP, while projections from benchmarks that do not include such gains be made with double-deflated GDP[2].

In economic history time-series projections are very common. Although a few alternative datasets with several benchmarks exist, the literature has largely relied on the database of Maddison and his successors[3]. In this database, GDP per capita is projected from a 1990 benchmark (Maddison 1995, p.98). This benchmark does not use prices for imports and exports. Hence, it includes trading gains. In the sake of coherence the time-series used for extrapolation should also include these effects. Only then, such projections are methodologically consistent.

The remainder of this paper will compute the different deflation procedures for Swiss GDP and show that the gains from relative price changes have been substantial, so that projections from the 1990 Maddison benchmark are strongly biased if they are based on double-deflated GDP (per capita) series.

3. Swiss GDP and value added, 1890 to 1990

3.1. GDP from the expenditure approach

Appendices 1 and 4 describe the sources and methods used to measure Swiss GDP and GDI by expenditure. Figure 2 illustrates both series and the decomposition of trading gains. The top row shows real GDP (equation 5) and real GDI (equation 8). The two series coincide in the base year highlighted by the black dot. The difference between the two series in a particular year corresponds to gains from relative price changes relative to the base year. Row 2 illustrates these trading gains (equation 9) and their decomposition into gains from changes of the real exchange rate and the terms of trade (equation 10). Note that positive gains from relative price changes imply a negative effect in periods before the base year and a positive effect after the base year. Row 3 shows the relative price changes and row 4 displays the share of exports in aggregate demand, which weights the impact of a terms of trade change, while 1 minus this share weights the impact of real exchange rate fluctuations.

Figure 2

During the period 1892 to 1930 there was only a weak trend in relative prices. Terms of trade worsened slightly and the real exchange rate appreciated slowly. During WWI, Switzerland suffered a negative terms of trade shock and an increase of the price of imports relative to domestic goods, but this shock was temporary and relative prices went back to the pre-war trajectory. The stability of relative prices translated into a parallel evolution of real GDP and GDI until WWI. The shock on relative prices during the war led to a temporarily increased difference between the two measures, but during the 1920s real GDP and GDI again evolved in parallel.

A new pattern set in with the Great Depression, when terms of trade improved significantly and the real exchange rate started to appreciate at a faster rate. The decrease of the real exchange rate was temporarily compensated after the devaluation of the Swiss franc in 1936 but terms of trade remained above the 1930 level. During the second half of the 20th century this pattern continued. The real exchange rate fell continuously so that in 1990 domestic goods were worth twice as many imported goods as in 1948. At the same time terms of trade improved substantially, so that in 1990 a given amount of exports was worth 60% more import goods than in 1948. This translated into a faster growth rate of GDI compared to real GDP. The graph in row 2 exhibits constantly rising trading gains, mainly driven by the real exchange rate effect.

Equation (10) shows that the impact of terms of trade increases with openness defined as the share of exports in aggregate demand, whereas the impact of the real exchange rate increases with the share of domestic expenditure in aggregate demand. As can be seen from the bottom row of figure 2, domestic expenditure was always the clearly dominant part of aggregate demand. Therefore, a change of the real exchange rate had a stronger impact than an equivalent change in the terms of trade. Accordingly, the real exchange rate effect was usually dominant.

The strong drop of the real exchange rate was therefore the main driver of the discrepancy between GDP and GDI.

3.2. GDP from the production approach

Appendices 2 and 3 report the data used for the computation of GDP from the production approach. Figure 3 plots double-deflated and single-deflated GDP from the production approach (equations 11 and 12) and the difference between the two, which captures gains from changes of industry terms of trade relative to the base year (equation 13). Again in periods before the base year positive gains from industry terms of trade result in negative values and in periods before the base year positive gains from industry terms of trade result in positive values. Until 1930 double- and single-deflated value added evolve in parallel, but thereafter the two series exhibit clearly different growth rates. Gains from relative price changes show no trend before 1930 but rise strongly between 1930 and 1990.

Figure 3

Figures 4 and 5 show the contribution of each industry to the deviation between single- and double-deflated value added (equation 13). Construction was among the main contributors in all three periods, the metal industry only from 1929 to 1960, the machine industry as well as repairs after 1960, and watchmaking after 1970. The food industry and hotels and restaurants were also important contributors as well as public administration, health care, consulting and engineering. Most of these industries have benefitted from cheap imported intermediate goods and/or fast growing output prices.

Figures 4 and 5

3.3. Money madness, export specialization, and corporatism

In this section I provide a historical explanation of the relative price shifts observed in Switzerland between 1930 and 1990. Three particularities of the 20th-century Swiss economy are crucial in this respect: the extremely strict hard currency policy, Switzerland's specialization in high quality exports, and corporatist arrangements.

Monetary and financial stability has been the main priority of Swiss economic policy making since 1918. Until 1945 the Swiss national bank strictly followed the rules of the gold standard. After WWI Switzerland managed to re-establish the pre-war parity of the franc as early as 1925; during the Great Depression the Swiss franc was the last currency to be devaluated in 1936; and Gold convertibility was suspended neither during the Great Depression nor during WWII (Bordo & James 2007). The appreciation of the Swiss franc in nominal and real terms continued also between 1945 and 1990. Under the Bretton Woods system Switzerland maintained its fixed exchange rate to the dollar, whereas several other currencies were devaluated in the early post-war years. But the franc was still undervalued so that in the 1950s and 1960s the expansive monetary policy of the USA, Switzerland's position as a tax haven, and large trade surpluses led to large capital inflows, inflation, and an appreciation of the real exchange rate (Halbeisen & Straumann 2012). After the adoption of flexible exchange rates capital inflows resulted in a continuous appreciation of the nominal exchange rate. During the 1970s crisis Switzerland implemented a monetarist policy, while many other countries responded with Keynesian monetary and fiscal expansion (Scharpf 2000). The strong appreciation of the Swiss franc limited price inflation of imports, while domestic prices rose quickly. This drove the long decline of the relative exchange rate illustrated in figure 3.

Switzerland's export specialization is also related to the appreciation of the Swiss franc, which forced exporters to move more and more into high quality niches, where competition operated through quality rather than prices. According to Müller (2012, p.406), in 1980 Swiss exports were already to 64% composed of high and medium high technology sectors. By 2003 this proportion even increased to 73%. Switzerland's peculiar export specialization combining intermediate goods imports with high quality final goods exports translated into export prices growing faster than import prices and the resulting improvement of terms of trade seen in figure 2.

The third driver of relative price changes came from Switzerland's corporatist regulations. The early development of the Helvetic economy occurred within weak institutional structures that made an interventionist economic policy impossible (Siegenthaler 1982). Toward the end of the 19th century and particularly during WWI, however, the Federal state's means of intervention increased and several interest groups developed close contacts to policy makers pushing for protection of domestic industries (Humair 2004). During the interwar period this tendency was re-enforced and complemented with the formation of powerful cartels that regulated production, prices, and distribution in numerous domestic sectors, notably agriculture and the food industry with its famous cheese cartel (Tissot & Moser 2012), construction and associated material industries (Cortat 2009; Hiestand 2010; Tissot & Moser 2012), but also the watchmaking industry (Piotet 1988). In 1947, finally, interest group participation was institutionalized in a series of amendments to the Federal constitution (Kriesi 1998, pp.187–192). Corporatist regulations have contributed to the distortion of relative prices, namely between prices of final goods and prices of intermediate goods. This can be illustrated with the divergence between the consumer price index, and the domestic producer price index. Between 1948 and 2003 consumer prices have increased by 376%, while domestic producer prices increased by only 147% (HSSO H.39). This leaves comfortable margins for industries that buy and sell within Switzerland and contributes strongly to the improvement of industry terms of trade analyzed in section 3.2.

3.4. World War I and the Great Depression as policy shifters

Probably the most striking element of figures 2 and 3 is the sharp contrast between the periods before and after 1930. How can we explain this sharp transition from stable to constantly shifting relative prices? The monetary disruptions during WWI and the Great Depression were two key episodes that determined this transition. This appears clearest in the realm of monetary policy, but it is also linked to a strengthening of corporatist and protective arrangements during the Great Depression.

Until the foundation of the Swiss National Bank in 1907, Switzerland depended heavily on the French financial market and the Swiss franc suffered from weakness against the French currency. The monetary policy of Switzerland was therefore de facto determined by the Banque de France (Bordo & James 2007). At the outbreak of WWI the Swiss National Bank had only limited experience. So far its policy actions relied on the gold standard and the "Real bills doctrine". In combination these two elements were meant to assure that the provision of liquidity went hand in hand with the real development of the economy. But when convertibility was suspended during the war, the Swiss National Bank started to rediscount public sector bills and purchase large amounts of gold. The consequent increases of the monetary mass led to strong inflation reaching 25 percent in 1918 (Ruoss 1992; Bordo & James 2007). Public accusations and political pressure on the national bank followed and the socially disruptive effect of inflation unloaded in a general strike in 1918 (Halbeisen & Straumann 2012). As a reaction to the accusations, the Swiss National Bank started a more restrictive policy after WWI, which was accompanied by a strong deflationary movement and ultimately, in 1925, allowed for restoration of the pre-war parity (Bordo & James 2007). Both the depreciation of the real exchange rate and the degradation of terms of trade are clearly visible in figure 2 as well as the restoration of the prewar price structure.

The Great Depression magnified the effects of the shift to a more monetarist policy. According to Müller (2010), the fear of inflation was one of the main arguments against devaluation advanced by the governing board of the Swiss National Bank, along with the will to restore the stability of the international monetary order and the preservation of the reputation of Switzerland as a financial center. Surprisingly, there was a very large consensus in favor of this monetarist policy across most interest groups: export industries feared instability and rising import prices and saw deflation as a way to reduce the cost of labor; trade unions feared the increasing cost of living and concentrated their action on the elaboration of an initiative aiming to support wages;

while the tourism industry and the farmers' association feared to lose protection and direct state contributions in case of a devaluation.

The prominent fear of inflation and the will to restore the pre-war order shows to what extent the WWI experience has re-enforced the gold standard mentality. This stability bias was further strengthed by the fact that Switzerland had become an international financial center during the 1920s. The position of the farmer's association and the tourism industry also shows how monetary and fiscal stability is related to corporatist arrangements and trade policy. The combination of monetarist and fiscal rigor with compensation arrangements negotiated with interest groups has become a standard reflex to crises in 20th century Switzerland (Halbeisen & Straumann 2012). Complementing monetary and fiscal policy with other fields of intervention liberated these instruments from the need to accommodate other goals than monetary and fiscal stability. The combination of monetarism, corporatism, selective protectionism, and increasing specialization in high quality niches developed a self-sustaining dynamic, which led to continuous relative price changes. With the exception of a short adjustment after the devaluation in 1936, the real exchange rate has appreciated and terms of trade have improved steadily between 1930 and 1990 (see figure 2).

4. Swiss growth in international comparison

In this section I discuss the Swiss growth trajectory in international perspective. I project GDP per capita from the Maddison 1990 benchmark.

4.1. Projecting single-deflated or double-deflated series

In section 2, I argued that projections from the Maddison benchmark should be based on single-deflated GDP. My favorite estimates will therefore rely on the projection of single-deflated series. However, in order to highlight the importance of this methodological problem and to show why earlier estimates of Swiss GDP per capita have failed to give a plausible account of the Swiss growth trajectory, this paragraph compares projections with single- and double-deflated series. As the series in the Maddison update mainly relies on GDP from the production approach, I focus on value added leaving GDP by expenditure aside. Figure 6 plots single- and double-deflated GDP per capita projected from the 1990 benchmark together with the series from the Maddison database (Bolt & Zanden 2014). On the right hand axis I display the double-deflated to single-deflated ratio as well as the Maddison to single-deflated ratio[4].

The Maddison series is very close to my double-deflated series, as it relies on the same deflation procedure and to a large extent also on the same original sources. Slight differences arise between 1948 and 1960 because my series relies on the production approach, while the Maddison series relies on GDP by expenditure. A huge difference, on the other hand, arises between double- and single-deflated series. As one moves back from the benchmark, the gains from relative price shifts cumulate, so that by 1929 the projection of double-deflated GDP per capita lies more than 30 percent above the projection of single-deflated GDP per capita, and the Maddison series is almost 40 percent higher than the single-deflated series.

Clearly, in the case of Switzerland, where gains from relative price changes were very important, the choice of deflation method has a major impact on long-span international comparisons. Projections that rely on double deflation end up with much higher GDP levels for earlier periods. The Maddison series for Switzerland combines a benchmark, which includes gains from relative price differentials with a double-deflated GDP per capita series, which excludes these gains. This methodological inconsistency leads to GDP per capita levels that are between 30 and 40 percent too high for the period before 1930.

Three arguments can be advanced in favor of projection with the single-deflated series. The first argument is theoretical: time-series and benchmarks must be consistent in their treatment of gains from relative price changes. The second argument is historiographical: an alternative dataset from Prados de la Escosura (2000), the earlier Maddison series (Maddison 2003), and real wage comparisons from Studer (2008) suggest that Switzerland was not a very rich country in 1880. A third argument is provided by a benchmark comparison for 1905 computed in appendix 7. This benchmark corroborates the projection of single-deflated GDP per capita and contradicts the GDP per capita level implied by the projection with a double-deflated series.

4.2. Swiss GDP per capita in international comparison, 1851-2008

The projection presented in this section relies on single-deflated series only. For the period 1892-1990 I project a compromise estimate, which is the geometric mean of the GDI and single-deflated value added series presented in sections 3.1 and 3.2. The series is then extended backward to 1851 using value added per capita (appendix 5) and forward to 2008 using GDI per capita (appendix 6)[5]. Figure 7 plots the resulting growth trajectory together with the series that were presented in figure 1. Table 1 provides additional detail on the comparison.

The main conclusion is that Switzerland was much less rich than suggested by the Maddison database (Bolt & Zanden 2014). In fact in 1851, Swiss GDP per capita was more than 10% below the Western European average and almost 40% below UK GDP per capita. By 1880, it caught-up with the Western European average and by 1910 it became the richest economy of the sample with a GDP per capita level slightly above the USA and 49% above the European average. Due to the harsh crisis after WWI and the long stagnation during the Great Depression, more than half of the advantage over Western Europe was eroded by 1939. During WWII and the early post-war years Europe fell back so that Switzerland's advance was almost re-established by 1950. But during the strong postwar convergence process between European economies and the USA, Switzerland's advantage diminished again considerably, although Switzerland managed to maintain its second rank within 10% of the US level until 1990. The 1990s crisis stands out as a rather bad decade for the Swiss economy, when Swiss GDP per capita fell way back behind the USA and the advantage over Western Europe fell to its lowest level since 1890.

Figure 7

The trajectory of my GDP per capita series is clearly distinct from that of both Maddison series. The Maddison update (Bolt & Zanden 2014) suggests that Switzerland has become a rich economy before the mid-19th century and insinuates that the most important phases of Switzerland's ascension are to be found in earlier periods such as the 18th and early 19th centuries. The old Maddison series (Maddison 2003) suggests a gradual catch-up of Swiss GDP per capita until 1939 and a huge bounce to the US level during WWII. My series suggests that it was during the period 1851 to 1910 that Switzerland became rich in comparison to other European countries. Another important revision concerns the period from 1945 to 1973. While the two Maddison series present Switzerland as a slow grower during the postwar boom, my series shows that Swiss growth was comparable to that of Western Europe, suggesting that Switzerland has clearly participated in the European convergence process toward the US level. However, the growth slack during the last three decades of the 20th century remains a fact even if gains from relative price changes are taken into account.

Table 1

4.3. Two growth regimes

The trajectory of my series has important implications for the discussion about the sources of Switzerland's wealthy situation. Different potential sources have been advocated: the strong financial sector, Protestantism, stability (including neutrality, corporatism, and monetary stability), and market access (including the geographical location, openness, and internal market integration).

The impact of Protestantism was most important from the 15th to 18th centuries, when protestant immigrants developed numerous proto-industrial activities in Switzerland. Market access was most important during the second half of the 19th century, when international markets integrated rapidly. The construction of the Swiss railway system and its connection to the European networks between 1850 and 1910 allowed Switzerland to take fully advantage of its central geographical location. The Swiss financial sector has become a global player only in the second half of the 20th century. Stability, as well, was a distinct characteristic of Switzerland during the 20th century, notably after 1930, when corporatist regulations were most important and the defense of the Swiss franc became the top priority of economic policy making.

My GDP series identifies the period 1850 to 1910 as the moment when Switzerland caught up with the richest economies. In doing so it draws the attention away from Protestantism and stability, highlighting instead the importance of the extraordinary market access that Switzerland enjoyed mainly due to its favorable geographical location.

Before the mid-19th century technology transfers through immigration were the most important aspect of market access. During the 15th and 16th centuries, Protestant immigrants have introduced a series of proto-industrial activities that were crucial for the further development of Switzerland (Bodmer 1946). However, until 1850 integration into world markets was limited to a few niches and concerned only a few regions. The rest of the Swiss economy was more backward and only weakly integrated with the more modern sectors and with world markets (Bernegger 1990). Only in the second half of the 19th century, which was characterized by fast international and internal market integration (Federico 2012; Jacks 2005; Frey 2006) a more significant part of the Swiss economy integrated in world markets. Access to raw materials now became important for a number of industries and immigration helped to provide the necessary labor force. During this period Switzerland was transformed to a modern and urbanized economy. This rapid integration movement launched a major growth spurt, which allowed Switzerland to become rich.

During the 20th century Switzerland became gradually less open. Also, market integration during the 20th century drove transport costs to such a low level that the consequence was rather re-dispersion then further concentration[6]. Under these circumstances Swiss economic growth took another character. It was less based on technological progress (*shifts of* the production possibilities frontier) than on price adjustments (*movements along* the frontier). As I have shown, strict monetary policy, cartelization, and specialization in high quality exports have led to changes of the relative price structure. In this period, the improvement of terms of trade and the appreciation of the real exchange rate have played the growth-enhancing role that falling trade costs have played during the second half of the 19th century. This type of growth entailed also a constant shift toward higher quality niches of the Swiss export industries, which was necessary to avoid a loss of competitiveness. However, this growth regime necessarily ran into decreasing returns as the scope to move to higher quality niches diminished and the high domestic price level started to depress consumption. The Swiss growth slack during the last three decades of the 20th century must be seen in the context of Switzerland's lacking openness and reduced scope for growth through relative price changes.

In sum, the Swiss growth trajectory can be separated into two phases, corresponding to two distinct growth regimes. The first growth regime, corresponding to the period 1850 to 1930, was based on rapid expansion of productive capacity. Profiting from market integration and a favorable geographical location, the Swiss economy experienced a rapid transformation and caught up with the richest economies of the world. Openness, and flexibility were the key characteristics that allowed for this strong growth performance. The second growth regime, corresponding to the period after 1930, was characterized by enormous changes of relative prices. Strict monetary policy, increasing specialization in high quality exports and corporatist arrangements led to a sharp appreciation of the real exchange rate and improved terms of trade. The gains realized from the reduced costs of imports contributed significantly to economic growth. But the high prices of exports and domestic goods also reduced export competitiveness and depressed domestic consumption, so that this growth regime ultimately ran into decreasing returns. While the first growth regime built on openness and flexibility, the second regime was characterized by the motivation to maintain and protect the acquired wealth.

5. Conclusion

This paper addresses a methodological problem: the distinction between single and double deflation in historical national accounting. A coherent framework is developed including a decomposition of economic growth into increases of productive capacity, gains from terms of trade, and real exchange rate effects. Switzerland serves as an exemplar case and new series of

GDP by expenditure and value added by industry from 1851 to 2008 are constructed. Trading gains, notably gains from the appreciation of the real exchange rate made a significant contribution to Swiss economic growth between 1930 and 1990. Negligence of these gains is the reason why earlier long-span international comparisons of Swiss GDP failed to give a plausible account of Switzerland's trajectory. A new internationally comparable series of Swiss GDP per capita is proposed, which shows that 19th and early 20th-century Switzerland was much less rich than suggested by the Maddison database (Bolt & Zanden 2014) and that Swiss growth during the post-WWII golden age was better than previously thought.

Three characteristics of the post-1930 Swiss economy can explain the strong shifts in relative prices that led to important trading gains: the hard currency policy, the specialization in high quality export goods, and corporatist arrangements. The post-WWI crisis and the Great Depression triggered a dynamic in which these characteristics were constantly reinforced, leading to continuous shifts of relative prices. Hence, two growth regimes can be distinguished. The first regime, before 1930, draws on openness and flexibility and implies fast growth of productive capacity and structural change. The second regime, after 1930, is built on the motivation to protect and maintain accumulated wealth and implies important gains from relative price changes.

Both regimes are prototypical for small countries in the sense that the sources of the success or failure of such economies are strongly dependent on the relation that they entertain with other countries. The Swiss success was built on its favorable geographical location and openness to immigration, technology transfers, and trade. In the 19th century, market integration was the trigger of a rapid growth spurt and in the 20th century, Swiss growth depended on constantly falling relative prices of imports. The Swiss growth slack after 1973, on the other hand was due to lacking openness and decreasing scope for gains from relative price changes. While the sources of growth for large economies are largely internal, the determinants of small countries' trajectories lay in their relation to other economies, i.e. market integration, terms of trade, and real exchange rates.

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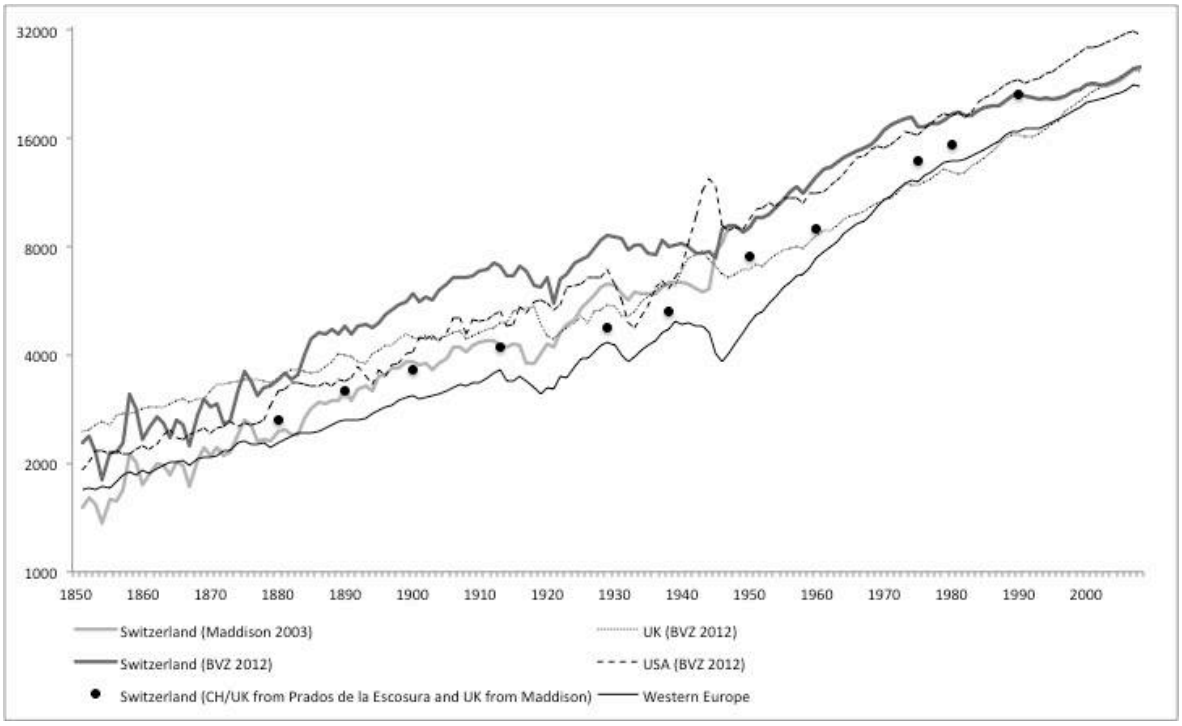
Tables and figures

Figure 1: Swiss GDP per capita according to different sources (in 1990 Geary-Khamis Dollars)



Sources: see text.

Figure 2: RGDP, GDI, and decomposition of trading gains, 1892-1990

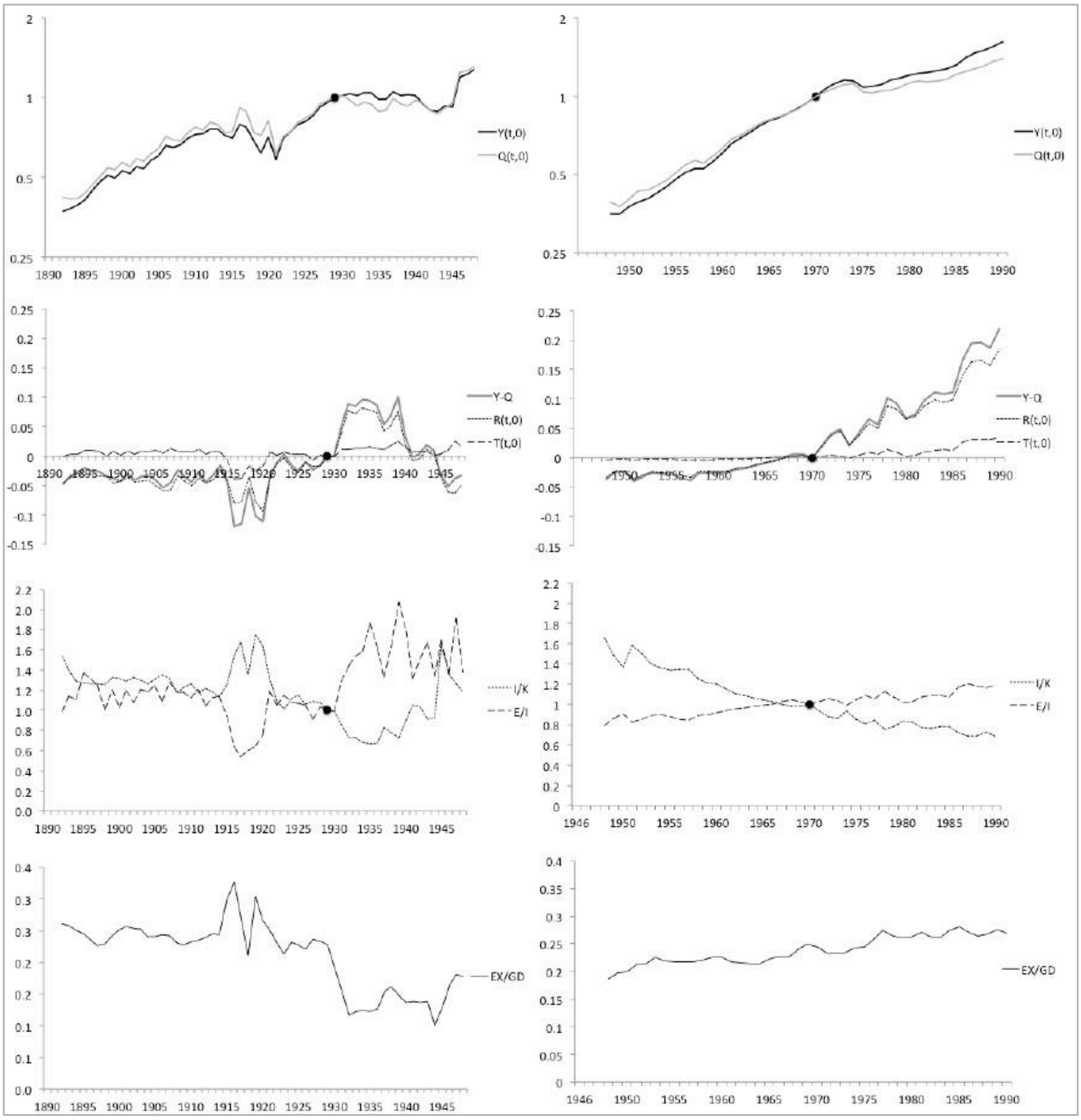
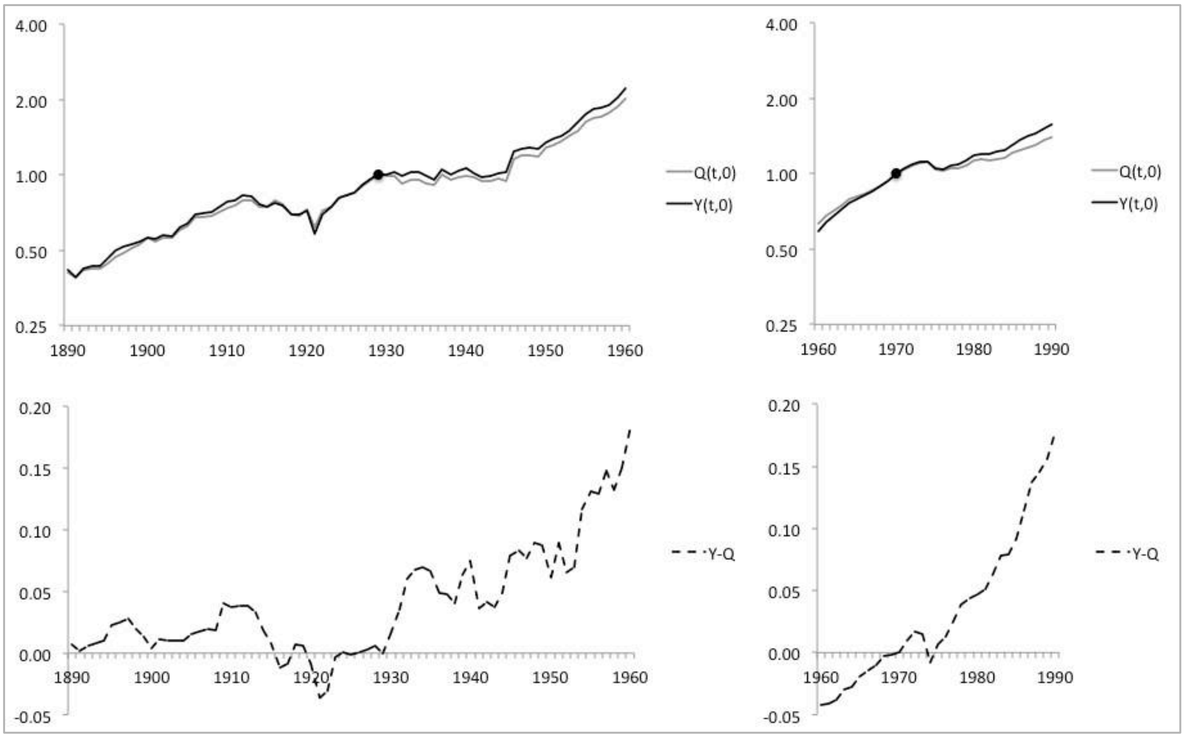
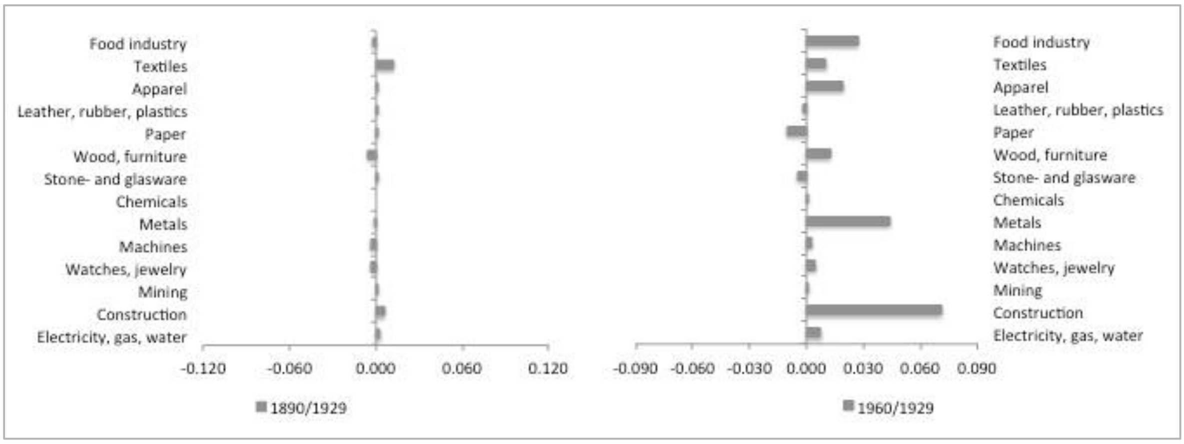


Figure 3: Double- and single-deflated GDP (value added), 1890-1990 (in Mio 1990 Geary-Khamis dollars)



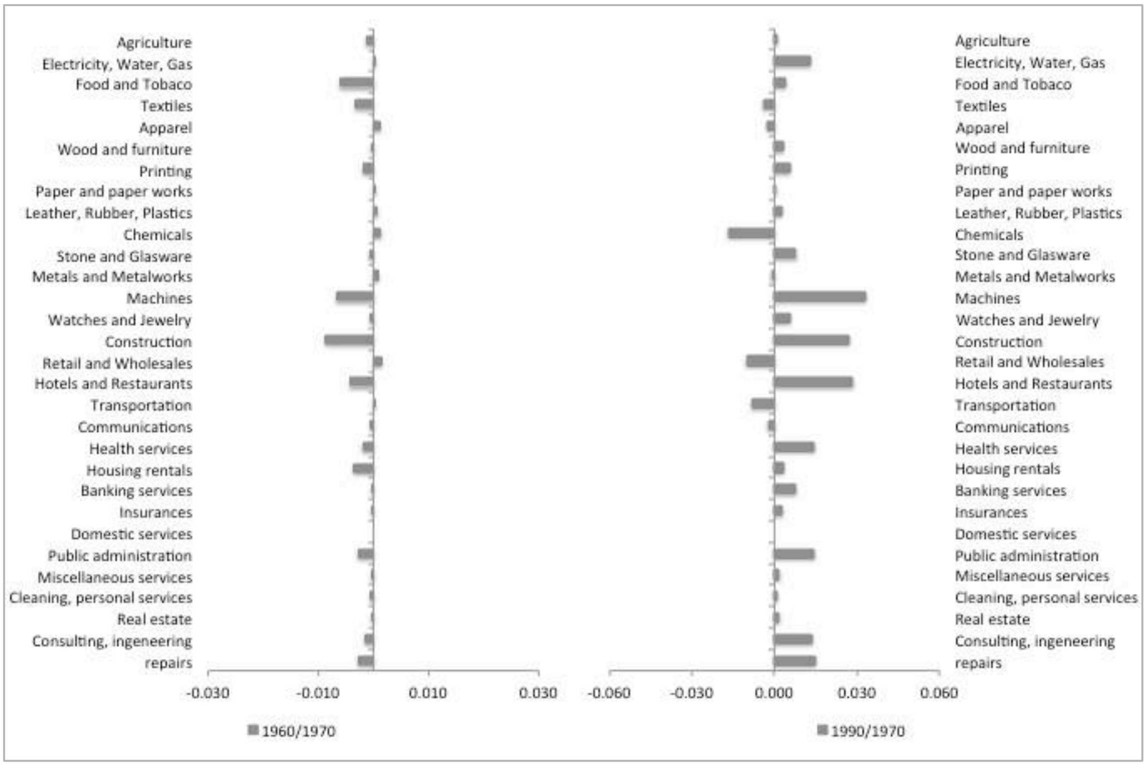
Note: see appendices A2 and A3 for a detailed description of sources and methods of computation. Note that the so-called double-deflated series for the period before 1960 is only partially double deflated, because no input prices are available for the different subdivisions of agriculture and services.

Figure 4: Industry contribution to gains from relative price changes, 1890-1929 and 1929-1960



Note: Decomposition of the difference between single- and double-deflated value added (equation 13). For the service and the agricultural sector as well as for printing and miscellaneous industries double-deflation is not possible. In periods before the base year positive industry terms of trade gains imply a negative value (left panel). In periodes after the base year positive industry terms of trade gains imply a positive value (right panel). Note that the left panel shows a cumulative effect over 39 years, while the right panel shows an effect over 31 years. Scales are adjusted accordingly.

Figure 5: Industry contribution to gains from relative price changes, 1960-1970 and 1970-1990



Note: Decomposition of the difference between single- and double-deflated value added (equation 13). In periods before the base year positive industry terms of trade gains imply a negative value (left panel). In periodes after the base year positive industry terms of trade gains imply a positive value (right panel). Scales are again chosen in accordance to the length of the period.

Figure 6: Double- and single-deflated GDP per capita, 1890-1990 (in 1990 Geary-Khamis dollars)

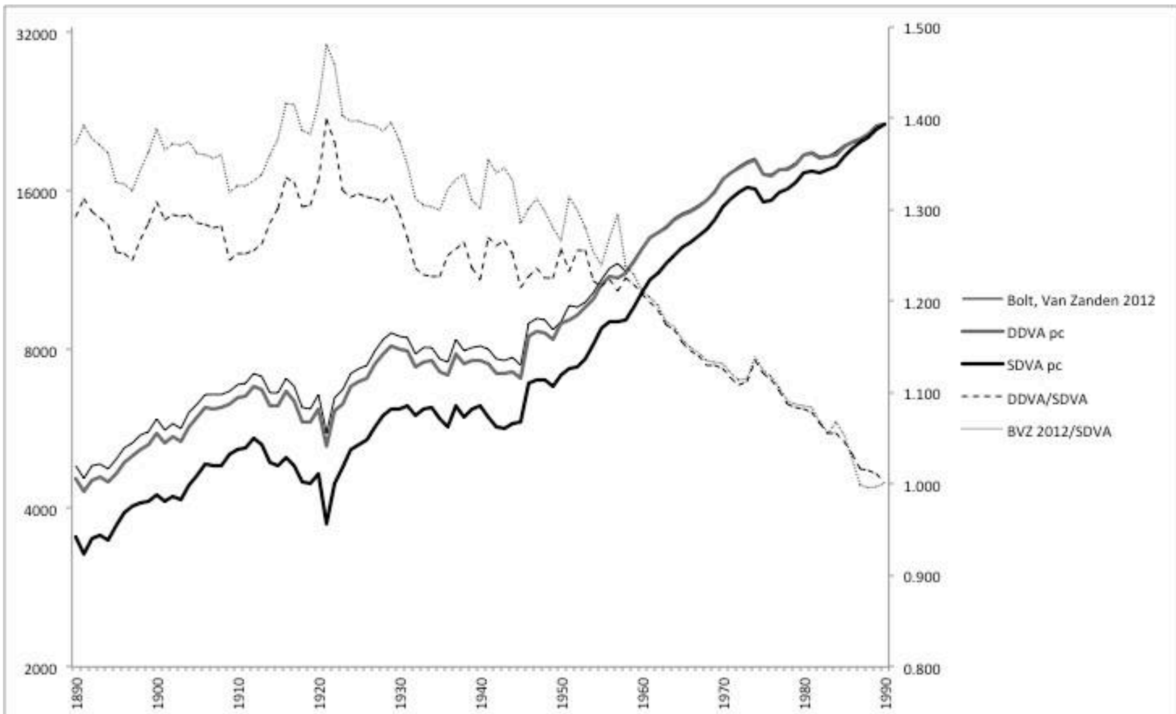


Figure 7: Swiss real GDP per capita in international comparison (in 1990 Geary-Khamis dollars)

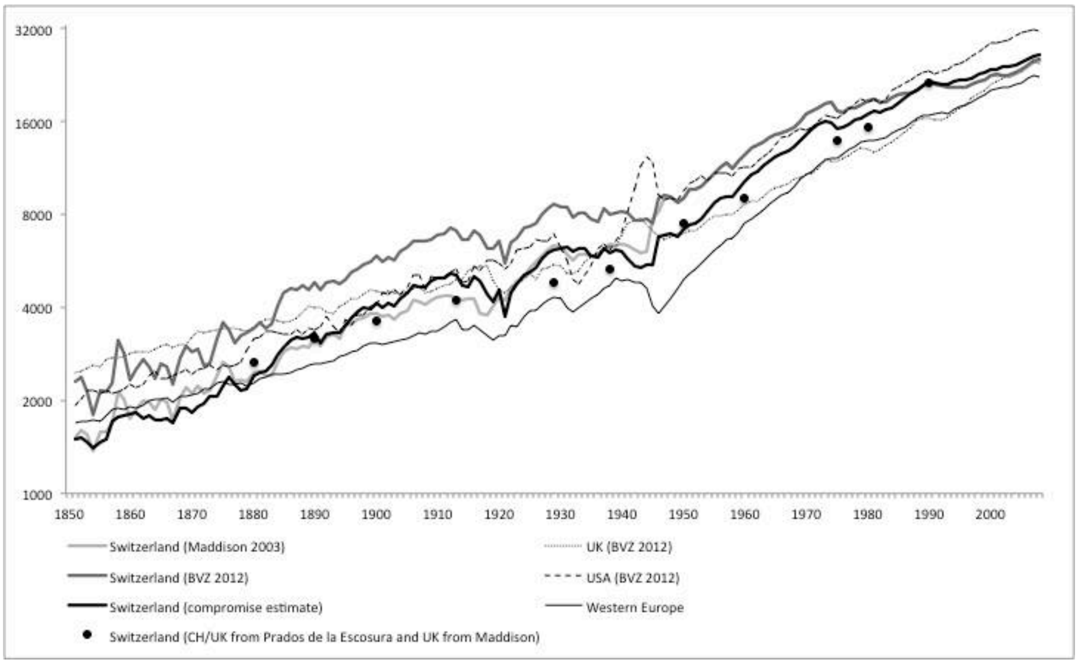


Table 1: Swiss GDP per capita in international comparison 1851 to 2000

	Ranking Switzerland among 13			Ratio Switzerland/Europe 12			Ratio Switzerland/Highest		
	Maddison 2003	BVZ 2012	Compromise estimate	Maddison 2003	BVZ 2012	Compromise estimate	Maddison 2003	BVZ 2012	Compromise estimate
1851	8	3	8	0.899	1.350	0.892	0.618	0.935	0.613
1875	4	1	5	1.144	1.543	0.969	0.770	1.046	0.651
1882	5	2	5	1.005	1.426	1.038	0.659	0.942	0.681
1890	5	1	4	1.209	1.817	1.253	0.794	1.205	0.823
1900	3	1	2	1.247	1.899	1.335	0.853	1.313	0.915
1910	3	1	1	1.296	2.034	1.492	0.873	1.387	1.008
1922	3	1	4	1.313	1.828	1.271	0.834	1.171	0.806
1929	2	1	2	1.460	1.974	1.423	0.918	1.252	0.894
1939	2	1	3	1.277	1.615	1.229	0.969	1.233	0.932
1945	2	2	3	1.898	1.832	1.359	0.662	0.638	0.469
1950	2	2	2	1.833	1.833	1.461	0.948	0.948	0.750
1960	1	1	2	1.661	1.661	1.364	1.100	1.100	0.898
1973	1	1	2	1.508	1.508	1.331	1.091	1.091	0.959
1980	1	1	2	1.345	1.345	1.218	1.011	1.011	0.913
1990	2	2	2	1.280	1.280	1.280	0.926	0.926	0.926
2000	4	4	3	1.116	1.119	1.163	0.783	0.785	0.817
2008	5	3	3	1.123	1.131	1.177	0.803	0.809	0.843

Sources: see text.

12 Western European countries: Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Sweden, Switzerland, United Kingdom according to Bolt and Van Zanden (2013).

[1] This is a frequently made assumption in the national accounting literature (Kohli 2004; Feenstra et al. 2015, p.3162). It means that all imports are intermediate goods, which is a reasonable assumption, because a large part of international trade is trade in intermediate goods. Even imported consumption goods usually go through the national production sector at least for distribution. This assumption is also consistent with national accounts and with the data used in this paper, because import and export prices are provided by the customs administration and correspond to values of goods when they cross the border, not when they are bought by final consumers in Switzerland or abroad (Kohli 2004).

[2] Alternative explanations for the inconsistency between projections and benchmarks are provided by McCarthy (2011). Feenstra et al. (2009) elaborate an analytical framework for making real income comparisons across time and space consistent. Their solution relies on constant reference prices.

[3] Ward and Devereux have elaborated punctual benchmarks calculating historical PPPs, and Prados de la Escosura has applied a short-cut method to predict PPPs from structural regressions on the level of nominal GDP per capita and a few additional control variables (Ward 2001; Ward & Devereux 2003; Prados de la Escosura 2000).

[4] The corresponding graph for GDP from the expenditure approach looks very much alike.

[5] The data on exports and imports before 1892 is too rudimentary to compute GDP by expenditure. Only value added by industry can be used for this period. For the period after 1990 the data on GDP from the production approach is highly fragmented, because industrial classifications have changed several times. A contiunuous series of value

added is available only for very broad sectors. Therefore, I decided to rely only on the expenditure approach for this period.

[6] New economic geography models imply that agglomeration ensues when transport costs fall from high to intermediate levels. But as transport costs fall to a level where they become negligible, economic activity re-disperses (Fujita et al. 2001).

Trading gains: New estimates of Swiss GDP, 1851 to 2008.

Online Data Appendix

This appendix provides further detail on the data and methods used in the elaboration of Swiss GDP by expenditure and value added by industry from 1851 to 2008. These series have been put together from a number of different pieces. Table A1 provides an overview of these different parts.

Table A1

The year 1990 has been used as a benchmark for putting the different pieces together. This choice is mainly motivated by the fact that the Maddison database relies on a 1990 benchmark comparison of international price levels. Using my series to project backward and forward from the 1990 level of the Maddison database yields Swiss GDP and value added in 1990 Geary-Khamis dollars.

All the different datasets have been revised to a certain extent in order to make them compatible and to elaborate each time one series that accounts for gains from relative price changes and one that excludes these gains. Sections A1 to A4 of this appendix discuss the sources and methods applied to the different parts. The presentation follows the order in which these datasets were elaborated.

Appendix 1: GDP by expenditure 1948-1990

The Federal Statistical Office has published official annual estimates of GDP by expenditure since 1948. In 1977 and 1983 two volumes compiled, revised, and homogenized estimates in current prices and in constant prices of 1970 (BFS 01, BFS 02). Annual publications have reported revised estimates using the same base year until 1987, whereas from 1987 onwards, 1980 was chosen as a base year (BFS 03).

I took nominal GDP directly from the original source and used the price data of individual components of GDP to deflate nominal GDP according to the different methods presented in the paper. In order to compute coherent price series, I rebased the prices of the years 1987 to 1990 to the 1970 base year. The resulting GDP and GDI series are discussed in the paper.

Appendix 2: value added by industry 1960-1990

For this period, there are no official estimates of value added by industry. The Federal statistical office has computed only four production accounts, namely in 1970 (BFS 01), 1975 (BFS 02), 1985 and 1990 (BFS 04). Moreover, all these accounts are based on different industrial classifications. Only the last two production accounts are comparable.

A group of researchers of the University of St. Gallen funded by a national research project has elaborated industry value added estimates for the period 1960 to 1981. A detailed description of the applied methods and sources was published in 1983 (Kneschaurek et al. 1983) and an update with more detailed data for the service sector was made available in 1984 (Meier 1984). These publications also report detailed data on prices and quantities. As it turns out this database has been regularly updated until 1990 and has then been published in the historical statistics of Switzerland (HSSO Q.02). Unfortunately, no description of the methods and sources used in these updates was published and detailed data on prices and quantities is not available any more. But closer scrutiny of the methods described in the 1980s reveals a major incoherence, in particular with respect to the difference between single-deflated and double-deflated value added. In fact, the estimates of HSSO Q.02 rely on price and quantity series for output only, because no data on intermediate products was available on an annual basis for this period. The share of value added in output value was taken in nominal terms from the production accounts for 1970 and 1975 and extrapolated for all other years. If anything, this would be closer to single-deflated value added. However, in a second step all industries' value added was adjusted to the official double-deflated GDP by expenditure.

In order to solve this incoherence and be able to measure the impact of relative price changes on GDP and value added, I have decided to replicate and extend the study of the 1980s. My replication uses more detailed data for the service sector, as proposed by Meier (1984), and it is not limited to output price and quantity series. In order to be able to distinguish between double-deflated and single-deflated value added I estimated prices and quanties for inputs using data from the punctual production accounts and from the input-output table for 1975 (Antille et al. 1983).

For the estimation of output value I projected data on quantities and prices backward from the 1990 production account. The nominal production value obtained from this projection was then double-checked against the values published in the production accounts for 1970, 1975, and 1985. For manufacturing industries the quantity indices are often easily available in the form of industrial production indexes. But adequate price series are more difficult to obtain. Most price series are not producer prices but consumer prices. In sectors with a significant proportion of external trade producer prices and consumer prices can differ significantly. In these industries it was therefore necessary to calculate producer prices using the following identity in nominal and real terms:

$$PQ = KN + EX - IM \qquad\qquad Q = N + X - M \tag{A.1}$$

This procedure is very data intensive because it requires detailed series on exports, imports, and domestic absorption, for quantities and prices. Table A.2 privides details on the sources of the data used for the backward projection of output values. In some service sectors, prices and quantities are difficult to measure. I therefore estimated value added from the income approach.

Since wages account for the major part of income in these sectors, I used only information on employment and wages, while neglecting income from other production factors.

I computed input prices as weighted averages of different industries' output prices using the input-output table for 1975 (Antille et al. 1983) for weighting:

$$p_{j,t} = \sum_{i}^{N} K_{i,t} * u_{i,j,1975} \tag{A.2}$$

where $p_{j,t}$ denotes input prices faced by industry j in period t, $K_{i,t}$ is the domestic[1] output price of industry i in period t, and $u_{i,j,1975}$ is the proportion of industry j inputs purchased from industry i in 1975.

For the computation of input quantities I used information from the production accounts for 1970, 1975, 1985, and 1990 (BFS 01, 02, 04). Eventhough theses production accounts are not exactly comparable, because they rely on different industrial classifications, they provide useful information on the share of intermediate consumption in gross production value. Using the ratio of output prices to input prices, the nominal share of inputs in gross production value can be converted into real terms:

$$\frac{p_i q_i}{P_i Q_i} \frac{P_i}{p_i} = \frac{q_i}{Q_i} \tag{A.2}$$

This ratio is basically a description of the production function defining quantities of input used per quantity of output produced. Changes in technology are more gradual and linear than changes in relative prices, so that short term fluctuations of the ratio defined in equation (A.2) must be rather small. Hence, I completed the missing values of the ratio by intrapolation and retropolation of the 1970-to-1990 trend backward from 1970 to 1960. Finally, the ratio can be multiplied with Q_i to obtain input quantities q_i.

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[1] Note that I use domestic output prices K rather than producer prices P or import prices I. Justification for this choice is apparent from equation (A.1). Intermediate products are either produced domestically or imported. That is they are counted either in $Q - X$ or in M. Therefore, it is better to use $K = (PQ - EX + IM)/N$ than P or I.

A cross-check of these estimates can be done by comparing total value added to the official estimates of GDP by expenditure (BFS 01, 02, 03). The evolution of double-deflated value added and real GDP by expenditure is almost identical (figure A.1). This confirms that the input and output quantity series are reasonably accurate. However, in order to construct a perfectly coherent system of national accounts, I multiply all constant-price series by the ratio of Real GDP to real value added. This adjusts double-deflated value added to real GDP but leaves relative industry weights unchanged. Figure A.2 compares nominal value added with adjusted quantities to nominal GDP by expenditure. Deviations are negligible. For the purpose of coherence between nominal GDP by expenditure and nominal value added I also adjust all price series.

Figures A.1 and A.2

Once all the input and output price and quantity series are established, it is simple to compute single-deflated value added as in equation (12) of the paper.

Appendix 3: value added by industry 1890-1960

For this period, I have used the value added estimates elaborated by Ritzmann and published in the historical statistics online (HSSO Q.17, Ritzmann –Blickenstorfer 2012). This database relies on double deflation for most manufacturing industries and on single deflation for services and agriculture. For agriculture this is probably not so problematic, because the share of intermediates in the production value is relatively small. For certain services this might be more problematic, when industry terms of trade gains are considered. However, when service industries are aggregated the problem should be negligible because few services are tradable, so that terms of trade gains and losses of individual service sector industries will compensate each other.

HSSO Q.17 provides nominal GDP, real GDP, indexes of industrial production and nominal production value. This allows for the calculation of output prices for all industries: for the manufacturing sector the index of nominal production value divided by the index of industrial production yields an index of output prices. For all other industries (which were single deflated by output prices), dividing nominal value added by real value added yields an output price index. Output prices can then be used to deflate nominal value added, which is equivalent to single-deflation. Double-deflated value added corresponds to the estimates of Ritzmann. It must be noted however that these estimates are double deflated only for manufacturing industries.

Appendix 4: GDP by expenditure 1890-1948

For this period I combined price and quantity series on investment, imports, and exports from Hiestand et al. (2012) with nominal GDP from the production approach (Appendix 3). Domestic expenditure is calculated as the residual remaining after subtraction of investment, imports and exports. Deflators for investment, imports, and exports are taken from Hiestand et al. (2012). Domestic expenditure was deflated with a consumer price index.

The Swiss historical statistics provide a CPI that covers the shole 19^{th} nd 20^{th} centuries (HSSO H.39) This index has been recomposed from different sources of hetergeneous quality. For the period after 1914, the index relies on official retrospective statistics of the Federal statistical office. From 1890 to 1914, the index evolves like the consumer price index elaborated for the National research project Real wages of Swiss industrial workers 1890 to 1921 (HSSO H.18). For the period vefore 1890 the series seems to be of inferior quality. This can be seen by simple inspection, because the index is subject to much higher volatility in this period. Higher volatility could of course be due to weaker market integration and efficiency. However, the fact that volatility decreases abruptly in 1890, when the more elaborated series begins, suggests that the strong fluctuations are due to the weak statistical basis of the index. In order to make the series more homogeneous I decided to smooth the series before 1890 with a five year moving average. The movement of the resulting index was used to project the Federal statistical office's CPI backward until 1851.

Appendix 5: Value added by industry 1851-1890

For this period I use nominal value added by industry estimates from the *Nationalfondsprojekt Gelmenge und Wirtschaftswachstum in der Schweiz 1851-1913* (NFP 1990). This was the first attempt to estimate a continous series of value added by industry for the period before WWI. This series was not connected to any benchmark production account so that the level of individual and aggregate value added series is questionable. The authors of the project were aware of this shortcoming and noted that the value added series by industry were more reliable in terms of their evolution over time than in terms of absolute level (Projer 1990, p.3). Also the authors were unable to estimate value added of all industries. In manufacturing, the industries for which estimates were elaborated accounted for approximately 82% of employment. Projer solved this problem by assuming that the industries for which they had no estimates evolved in parallel to the industries for which they managed to estimate value added. Hence he simply divided the sum of industires' value added by 0.82 in order to estimate value added of the entire sector.

To project GDP backward from 1890 to 1851, I spliced nominal value added industry-wise. This allows for an adjustment of inter-industry productivity differentials to those implied by HSSO Q.17, which relies on much more detailed data and draws on more information from direct industry comparisons. It also implies that industries that could not be estimated in the *Nationalfondsprojekt* are now supposed to evolve in parallel with a more narrowly defined aggregate than the entire manufacturing sector. For example, the missing value added series for the wool industry is assumed to evolve in parallel to the estimated textile industries, not the entire manufacturing sector as in Projer's approach. In a second step, I deflated all industries' value added series with the consumer price index described in the last section.

Appendix 6: Real GDP and GDI by expenditure 1990-2008

For this period, I used data from SECO (2015). Nominal and Real GDP is provided directly in the source along with price indices. GDI was computed according to equation 8. The movement of the different series was then used to project GDP forward from the 1990 benchmark.

Appendix 7: Cross checking with a 1905 benchmark comparison

In this section I use a benchmark comparison for 1905 to evaluate the accuracy of the long-term growth rate of the different GDP series. This empirical strategy rests on the assumption that comparisons from time-series projections and direct benchmark comparisons lead to the same results. This is of course never exactly the case. The inconsistency between benchmark comparisons and time-series projections has been widely discussed in the national accounting literature. In particular, the discrepancies between projections from the 2005 ICP benchmark and direct comparisons from the 2011 ICP benchmark have attracted much attention (see the discussion in section 2.5 of the paper). As Inklaar and Rao highlight, these large discrepancies cast doubt on the usefulness of time-series projections: *"Most importantly, the difference between the original ICP 2005 and ICP 2011 suggested that datasets based on extrapolating relative prices from a benchmark comparison to earlier years were strongly biased. This, in turn, could have had serious consequences for research based on such datasets, which include the World Development indicators of the World Bank, the Maddison database (Bolt and van Zanden, 2014) and parts of the Penn world table (Feenstra, Inklaar and Timmer, 2015)."* (Inklaar & Rao 2016, p.4). However, by constructing a counterfactual 2005 benchmark, which is methodologically in line with the 2011 benchmark they significantly reduce the discrepancies and conclude: *"Our results suggest that such a fundamental reconsideration is not necessary, since correcting for measurement differences through our counterfactual for 2005 eliminates the systematic differences between extrapolations from the counterfactual for 2005 and the ICP 2011 benchmark comparisons."* (Inklaar & Rao 2016, p.4).

This raises a first question for the benchmark proposed in this section: is this benchmark methodologically consistent with the Maddison benchmark? It is not in the sense that it relies on much simpler methodology and much less data. But it is consistent in the sense that it does not include prices for exports and imports and hence, like the Maddison benchmark it includes trading gains. Another question is how consistent the two benchmarks are with the time-series used for the projection. This question goes to the hart of the argument of this section: projections based on single-deflated series are consistent with the two benchmarks and will be corroborated, while projections based on double-deflated series are not consistent with the two benchmarks and will be rejected.

Table A3 provides two types of international comparisons of UK, US, and Swiss GDP per capita levels around 1905: a benchmark comparison in 1905 PPP pounds and indirect comparisons based on time series projections from the 1990 benchmark in Geary-Khamis dollars. The top panel gives details on price levels of different consumption goods around 1905. It reveals that Switzerland had the lowest and the USA the highest price level. The second panel uses these price levels to construct 1905 PPPs and convert all GDP per capita estimates into 1905 PPP pounds, while the third panel reports the GDP per capita levels of different time series projections in 1990 Geary-Khamis dollars. The bottom panel expresses these different comparisons in relative terms.

Table A3

As can be seen the comparisons from direct benchmarks and time series projections for the US-UK comparison corroborate each other quite well: the benchmark comparison suggests that the US GDP per capita was 5.6 percent above the UK level, while the time series projection yields a GDP per capita level that lays 3.1 percent above. The comparisons with Switzerland are more ambiguous. The benchmark comparison suggests that the Swiss GDP per capita level was 11.6 percent lower than the UK and 16.3 percent lower than the US level. The relative GDP per capita level resulting from the time series projection of the double-deflated GDP and value added series stands completely at odds suggesting that Swiss GDP per capita was around 30 percent higher than the UK and 26 percent above the US level. On the other hand, time series projections based on gross domestic income and single-deflated value added lay within a 15 percent margin of the benchmark comparison.

How about the accuracy of this benchmark. Of course, it is very simplistic, because the underlying consumption basket covers only a small part of GDP and the prices are from a few cities only. Certainly, this benchmark comparison is not sufficiently accurate as such, but it is sufficient to corroborate the projections based on single-deflated series and reject the projections based on double-deflated series, because the discrepancy between these two types of projections are so large. Future research should focus on the construction of benchmark comparisons that rely on more data and more sophisticated methodology.

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Tables

Table A1: Underlying data sources of partial GDP and value added series

<table>
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NFP 1990,</td></tr>
<tr><td>Appendix 4:
GDP by expenditure 1890-1948
HSSO Q.16,
Hiestand et al. (2012)</td><td rowspan="2">Appendix 3:
Value added by industry 1890-1960
HSSO Q.17,
Ritzmann 1998,
Ritzmann and David 2012.</td></tr>
<tr><td rowspan="2">Appendix 1:
GDP by expenditure 1948-1990
BFS 01,
BFS 02,
BFS 03</td></tr>
<tr><td>Appendix 2:
Value added by industry 1960-1990
HSSO Q.02,
Kneschaurek et al. (1983),
Meier (1984).</td></tr>
<tr><td>Appendix 6: GDP by expenditure 1990-2008
HSSO Q.16 (1990-2005),
BFS 05 (2005-2008)</td><td></td></tr>
</table>

Table A.2: Data on the movement of output quantities (Q) and prices (P)

Agriculture:

- Nominal production value (PQ): Endrohertrag from HSSO I.25
- Output producer prices (P):

  - Producer prices 1976-1990 from: Schweizerisches Bauernsekretariat (1978-1993);

  - Producer prices 1960-1976 from: Kneschaurek et al (1983)
- Production quantities (Q): PQ deflated with P

Food and Tobacco:

- Production quantities (Q): from HSSO K.15
- Export value (EX): from BFS historical tables, Aussenhandel T 6.5.2.3.2
- Import prices (I):

  - 1960-1987: Laspeyres index of implicit prices for 18 items from BFS, historical tables, Aussenhandel T 6.5.3.2.5;

  - 1987-1990: geometric average of world prices for 25 food itemsworld from Jacks et al. (2011).
- Import values (IM): from BFS, historical tables, Industrie und Dienstleistungen, Aussenhandel T 6.5.2.3.1
- Import quantities (M): IM deflated with I
- Export values (EX): from BFS, historical tables, Industrie und Dienstleistungen, Aussenhandel T 6.5.2.3.2
- Export prices (E):

  - 1960-1981: from Kneschaurek et al (1983)

  - 1982-1990: equal to I
- Export quantities (X): EX deflated with E
- Domestic consumption quantities (N): N = Q – X + M
- Domestic consumer prices (K): from GDP by expenditure (BFS 01, 02, 03)
- Production value (PQ): PQ = KN + EX – IM
- Producer prices (P): PQ / Q

Textiles:

- Production quantities (Q): from HSSO K.15
- Domestic prices (K):

  - 1960-1963: HSSO H.10 wholesale price textiles, leather, rubber;

  - 1963-1990: HSSO H.11 wholesale price textiles;
- Export values (EX): from SJ 1960-1990
- Export quantities (X):

- 1960-1986: from SJ

- 1987-1990: EX deflated with E

- Export prices (E):

  - 1960-1986: EX/X for different subcategories and aggregated with a Laspeyres index

  - 1986-1990: wholesale price index from HSSO H.11

- Import values (IM): from SJ 1960-1990

- Import quantities (M):

  - 1960-1986: from SJ

  - 1986-1990: IM deflated with I

- Import prices (I):

  - 1960-1986: EX/X for different subcategories and aggregated with a Laspeyres index

  - 1986-1990: Wholesale price index from HSSO H.11

- Domestic consumption quantities (N): N = Q – X + M

- Production value (PQ): PQ = KN + EX – IM

- Producer prices (P): PQ / Q

Apparel:

- Production quantities (Q): from HSSO K.15

- Export values (EX): from SJ 1960-1990

- Export prices (E): from E textiles

- Export quantities (X): EX deflated with E

- Import values (IM): from SJ 1960-1990

- Import quantities (M):

  - 1960-1986: from SJ

  - 1986-1990: IM deflated with I

- Import prices (I):

  - 1960-1986: IM/M for different subcategories and aggregated with a Laspeyres index

  - 1986-1990: Wholesale price index from HSSO H.11

- Domestic consumption quantities (N): N = Q – X + M

- Domestic prices (K): equal to I

- Production value (PQ): PQ = KN + EX – IM

- Producer prices (P): PQ / Q

Wood, furniture, and other industries (music instruments, toys, strollers):

- Production quantities (Q): HSSO K.15 (wood and cork) multiplied by the following ratio (employment in the wood and cork industry + employment in furniture and other industries) / employment in the wood industry
- Domestic consumption and production prices (P=K): geometric average of

  - 1960-1963 wholesale price index for construction wood from HSSO H.12

  and 1963-1990 wholesale price index for the wood and cork industry from HSSO H.11

  - 1966-1990: BFS, LIK 1966, 1977, 1982: Möbel

Paper, paperworks:

- Production quantities (Q): HSSO K.15
- Domestic consumption and production prices (P=K):

  - 1960-1963: wholesale price index of cellulose from HSSO H.12

  -1963-1990: wholesale price index of the paper industry from HSSO H.11

Printing:

- Production quantities (Q): HSSO K.15
- Domestic consumption and production prices (P=K):

  - 1960-1966: Kneschaurek et al. (1983)

  -1966-1990: BFS, LIK 1966, 1977, 1982, Zeitungen, Zeitschriften, Bücher

Leather, rubber, plastics:

- Production quantities (Q): HSSO K.15
- Domestic consumption and production prices (P=K):

  - 1960-1963: Kneschaurek et al. (1983)

  -1963-1990: wholesale price index from HSSO H.11

Chemical industry:

- Production quantities (Q): HSSO K.15
- Domestic prices (K):

  - 1960-1963: wholesale price index from HSSO H.10

  -1963-1990: wholesale price index from HSSO H.11
- Export quantities (X):

  - 1960-1986: SJ 1960-1987

  - 1986-1990: EX deflated with E
- Export prices (E):

- 1960-1986: SJ 1960-1987

- 1986-1990: wholesale price index from SJ 1992

- Export values (EX):

  - 1960-1986: E*X

  - 1986-1990: SJ 1986-1993

- Import quantities (M):

  - 1960-1986: SJ 1960-1987

  - 1986-1990: IM deflated with I

- Import prices (I):

  - 1960-1986: SJ 1960-1987

  - 1986-1990: wholesale price index from SJ 1992

- Import values (IM):

  - 1960-1986: I*M

  - 1986-1990: BFS, historical tables, tables hs-d-06.05.03.02.05 and hs-d-06.05.03.02.06

- Domestic consumption quantities (N): N = Q – X + M

- Production value (PQ): PQ = KN + EX – IM

- Producer prices (P): PQ / Q

Mining, stone, earth, and glas works:

- Production quantities (Q): HSSO K.15 (stone, earth, and glass works) multiplied by the following ratio (employment in the stone, earth, and glas industry + employment in mining) / employment in the stone, earth, and glas industry

- Domestic prices (K):

  - 1960-1963: wholesale price index from HSSO H.10

  -1963-1990: wholesale price index of from HSSO H.11

- Export quantities (X):

  - 1960-1986: SJ 1960-1987

  - 1986-1990: EX deflated with E

- Export prices (E):

  - 1960-1986: SJ 1960-1987

  - 1986-1990: equal to K

- Export values (EX):

  - 1960-1986: E*X

- 1986-1990: SJ

- Import quantities (M):

  - 1960-1986: SJ 1960-1987

  - 1986-1990: IM deflated with I

- Import prices (I):

  - 1960-1986: SJ 1960-1987

  - 1986-1990: equal to K

- Import values (IM):

  - 1960-1986: I*M

  - 1986-1990: SJ

- Domestic consumption quantities (N): N = Q – X + M

- Production value (PQ): PQ = KN + EX – IM

- Producer prices (P): PQ / Q

Metal industry:

- Production quantities (Q): HSSO K.15

- Domestic prices (K):

  - 1960-1963: wholesale price index from HSSO H.10

  -1963-1990: wholesale price index from HSSO H.11

- Export quantities (X):

  - 1960-1986: SJ 1960-1987

  - 1986-1990: EX deflated with E

- Export prices (E):

  - 1960-1986: SJ 1960-1987

  - 1986-1990: equal to K

- Export values (EX):

  - 1960-1986: E*X

  - 1986-1990: SJ

- Import quantities (M):

  - 1960-1986: SJ 1960-1987

  - 1986-1990: IM deflated with I

- Import prices (I):

  - 1960-1986: SJ 1960-1987

- 1986-1990: equal to K

- Import values (IM):

  - 1960-1986: I*M

  - 1986-1990: SJ

- Domestic consumption quantities (N): N = Q – X + M

- Production value (PQ): PQ = KN + EX – IM

- Producer prices (P): PQ / Q

Machines and vehicles:

- Production quantities (Q): HSSO K.15

- Domestic prices (K): Deflator of investment in equipment from GDP by expenditure (BFS 01, 02, 03)

- Export quantities (X): separate series for machines and vehicles aggregated with 1990 export values as weights

  - 1960-1986: SJ 1960-1987

  - 1986-1990: EX deflated with E

- Export prices (E): separate series for machines and vehicles aggregated with 1990 export values as weights

  - 1960-1986: SJ 1960-1987

  - 1986-1990: for machines equal to K; for vehicles from BFS, LIK 1982 (Fahrzeuge)

- Export values (EX): separate series for machines and vehicles

  - 1960-1986: E*X

  - 1986-1990: SJ

- Import quantities (M): separate series for machines and vehicles aggregated with 1990 export values as weights

  - 1960-1986: SJ 1960-1987

  - 1986-1990: IM deflated with I

- Import prices (I): separate series for machines and vehicles aggregated with 1990 export values as weights

  - 1960-1986: SJ 1960-1987

  - 1986-1990: for machines equal to K; for vehicles from BFS, LIK 1982 (Fahrzeuge)

- Import values (IM): separate series for machines and vehicles

  - 1960-1986: I*M

  - 1986-1990: SJ

- Domestic consumption quantities (N): N = Q – X + M

- Production value (PQ): PQ = KN + EX – IM

- Producer prices (P): PQ / Q

Watches and Jewelry:

- Production quantities (Q): HSSO K.15
- Export prices (E): geometric average of

  - apparatuses, instruments, watches, and jewelry: 1960-1986 from SJ and 1986-1990 from BFS, LIK 1982 (electric watches)

  - watches: 1960-1990 value of watch exports from HSSO L.13 divided by geometric average of the quantity indexes of exported watch mechanisms and watches

- Producer prices (P): equal to export prices

Construction:

- Production quantities (Q): Real GDP by expenditure (construction)
- Production prices (P): GDP by expenditure, deflator of construction

Electricity, gas, water:

- Production quantities (Q): HSSO K.15
- Domestic consumption (N): GES 1997, End consumption of energy in Terajoules (TJ)
- Domestic prices (K): GES 1997, consumer prices of gas and electricity, aggregated with 1990 consumption weights
- Import values (IM): gas imports from GES 1997 p.51, GES 1995 p.48
- Import quantities (M): gas imports in TJ from GES 1997 p.23 and SJ 1979 p.161
- Import prices (I): IM/M
- Export values (EX): exports of electricity from GES 1997 p.51, GES 1995 p.48
- Export quantities (X): exports of electricity from GES 1997 p.23, SJ 1979 p.161
- Export prices (E): EX/X
- Production value (PQ): PQ = KN + EX – IM
- Producer prices (P): PQ / Q

Retail and wholesales:

- Production quantities (Q):

  - Retail: Kleinhandelsumsätze from HSSO S.13 deflated with consumer price index from Stohr (2014)

  - Wholesales: Bundeseinnahmen aus der WUST from SJ 1960-1990 deflated with wholesale price index from BFS historical tables, prices, T.05.02.01

  - aggregation with the following weights: retail (0.36), wholesales (0.64) according to Kneschaurek et al. (1982)

- Production prices (P=K): see deflators of production quantities

Hotels and restaurants:

- Production quantities (Q): Hotel nights (nationals and foreigners) from HSSO M.07b and appartment location from HSSO M.11 (nationals and foreigners)
- Domestic prices (K): from GDP by expenditure, deflator of expenditures for leisure and education
- Import prices (I): from GDP by expenditure, deflator of expenditures abroad
- Import values (IM): Fremdenverkehrsbilanz, Einnahmen von Aufenthalten (BFS 06)

  - 1960-1985: SJ 1975, 1980, 1987/88,

  - 1985-1990: Fremdenverkehrsbilanz 1993 (BFS 06)
- Import quantities: IM/I
- Export quantities (X): Hotel nights (foreigners only) from HSSO M.07b and appartment location from HSSO M.11 (foreigners only)
- Export value (EX): expenditures from journeys abroad

  - 1960-1985: SJ 1975, 1980, 1987/88,

  - 1985-1990: Fremdenverkehrsbilanz 1993 (BFS 06)
- Export prices (E): EX/X
- Domestic consumption quantities (N): N = Q – X + M
- Production value (PQ): PQ = KN + EX – IM
- Producer prices (P): PQ / Q

Transportation:

- Production quantities (Q):

  - Rail passenger transportation: 1960-79 HSSO N.08; 1980-1990 SJ 1995 p.247

  - Rail freight transportation: 1960-1979 HSSO N.08; 1980-1990 SJ 1995 p.249

  - Air passenger transportation: 1960-1979 HSSO N.15; 1980-1990 SJ 1995 p.247

  - Air freight transportation: 1960-1979 HSSO N.15; 1980-1990 SJ 1995 p. 249

  - Water passenger transportation: 1960-1979 HSSO N.02; 1980-1990 SJ 1995 p. 247

  - Water freight transportation: 1960-1979 HSSO N02 and HSSO N03; 1980-1990 SJ 1995 p.249

  - Road freight transportation: 1960-1979 HSSO N02 and HSSO N03; 1980-1990 SJ 1995 p.249

  - Public road transportation of passengers: SJ 1995 p.247; 1961-1969, 1971-1974, 1976-1979: Intrapolation

  Aggregation to a single index using 1990 accounting revenues from Schweizerische Verkehrsstatistik 1990 (BFS 07, p. 102) as weights

- Domestic prices (K = P):

  - passenger transportation: 1966-90: BFS LIK 1966, 1977, 1982 (öffentlicher Verkehr); 1960-66: GDP by expenditure (BFS 01) Verkehrsausgaben

  - freight transportation: revenues per ton kilometer from rail freight transportation according to Schweizerische Verkehrsstatistik (BFS 07)

  Aggregation to a single index using 1990 accounting revenues from Schweizerische Verkehrsstatistik 1990, (BFS 07, p. 102)

Communication services:

- Production values (PQ): revenues of PTT (Public Post Telephone Telegraph company holding a monopoly until the 1990s) without gains from operations on capital from 1990,1985: SJ 1995 p.261; 1986-1989: intrapolation; 1962-1986: HSSO N.20; 1960-1961: HSSO N.20
- Domestic prices (K = P): 1966-1990: BFS LIK 1966, 1977, 1982); 1960-1965: GDP by expenditure (Verkehr)
- Production quantities (Q): PQ/P

Health care services:

- Production value (PQ): average health care costs per insurance holder from SJ 1973 and 1994 multiplied with total Swiss population
- Domestic prices (K=P): Deflator of Expenditure on health care from GDP by expenditure (BFS 01, 02, 03)
- Production quantities (Q): PQ/P

Real estate rentals:

- Production quantity (Q): from GDP by expenditure (BFS 01, 02, 03)
- Prices (P): from GDP by expenditure (BFS 01, 02, 03)

Banking sector:

- Production value (PQ): Revenues from interests, fees, trading, and other ordinary revenues from SNB 2015
- Prices (P): 1960-1966: consumer price index Stohr (2014); 1967-1976: BFS LIK 1966 (Dienstleistungen); 1977-1990: BFS LIK 1977, 1982 (private Dienstleistungen)
- Production quantities (Q): PQ/P

Imputed production value of banking services:

- Production value (PQ): margin between interest revenues and liabilities according to SNB 2015
- Prices (P): same as P of Banking sector
- Production quantities (Q): PQ/P

Insurances:

- Production value (PQ): contributions minus benefits according to HSSO P.03

- Prices (P): 1960-1966: consumer price index Stohr (2014); 1967-1976: BFS LIK1966 (Dienstleistungen); 1977-1990: BFS LIK1977, 1982 (private Dienstleistungen)
- Production quantities (Q): PQ/P

Domestic services:

- Production value (Q): real expenditures from GDP by expenditure (Ausgaben für Dienstbotenlöhne)
- Prices (P): deflator of expenditures from GDP by expenditure (Ausgaben für Dienstbotenlöhne)

Repairs (Income approach: projection with wL):

- Employment (L):

  - 1990 and 1985: from BFS 04

  - 1975: 1985 multiplied with 1975/1985 ratio from BFS BZ 1985

  - 1965: 1975 multiplied with 1965/1975 ratio from BFS BZ 1975

  - 1960-1965: movement of employment statistics from Meier (1983)

  - 1965 to 1975 and 1975 to 1985: intrapolation with constant growth rate and short-term fluctuations as in Meier (1983)

  - 1985-1990: intrapolation with constant growth rate and short-term fluctuations according to SJ 1991/92, Beschäftigungsindex
- Wages (w): BFS, Schweizerischer Lohnindex (BFS 08)
- Producer prices (P): same as machine industry

Real estate services (Income approach: projection with wL):

- Employment (L):

  - 1990 and 1985: from (BFS 04)

  - 1975: 1985 multiplied with 1975/1985 ratio from BFS, BZ 1985

  - 1965: 1975 multiplied with 1965/1975 ratio from BFS, BZ 1975

  - 1960-1965: movement of employment statistics from Meier (1983)

  - 1965 to 1975 and 1975 to 1985: intrapolation with constant growth rate and short-term fluctuations as in Meier (1983) and SJ 1989, Beschäftigungsindex 1982-1985

  - 1985-1990: intrapolation with constant growth rate and short-term fluctuations as in Meier (1983)
- Wages (w):

  - 1960-68: SJ, Lohn- und Gehaltserhebung, Banken, Versicherungen;

  - 1968-74: SJ, Lohn- und Gehaltserhebung, Dienstleistungen;

  - 1974-77: SJ, Lohn- und Gehaltserhebung, Immobilien;

  - 1977-86: SJ, Lohn- und Gehaltserhebung, Immobilien, Verleih;

- 1986-1994 Neue BIGA Unfallstatistik in (BFS 09): Immobilien, Vermietung Beratung

• Producer prices (P): from GDP by expenditure (BFS 01, 02, 03): Dienstleistungsexporte

Consulting and technical services (Income approach: projection with wL):

• Employment (L):

- 1990 and 1985: from BFS 04

- 1975: 1985 multiplied with 1975/1985 ratio from BFS, BZ 1985

- 1965: 1975 multiplied with 1965/1975 ratio from BFS, BZ 1975

- 1960-1965: movement of employment statistics from Meier (1983)

- 1965 to 1975 and 1975 to 1985: intrapolation with constant growth rate and short-term fluctuations as in Meier (1983) and SJ 1989, Beschäftigungsindex 1982-1985

- 1985-1990: intrapolation with constant growth rate and short-term fluctuations as in Meier (1983)

• Wages (w):

- 1960-1986 SJ, Lohn- und Gehaltserhebung;

- 1986-1990 BIGA Unfallstatistik in BFS 09

• Producer prices (P): from GDP by expenditure (BFS 01, 02, 03): Dienstleistungsexporte

Cleaning and personal services (Income approach: projection with wL):

• Employment (L):

- 1990 and 1985: from BFS 04

- 1975: 1985 multiplied with 1975/1985 ratio from BFS, BZ 1985

- 1965: 1975 multiplied with 1965/1975 ratio from BFS, BZ 1975

- 1960-1965: movement of employment statistics from Meier (1983)

- 1965 to 1975 and 1975 to 1985: intrapolation with constant growth rate and short-term fluctuations as in Meier (1983) and SJ 1987/88, Beschäftigungsindex 1982-1985

- 1985-1990: intrapolation with constant growth rate and short-term fluctuations as in Meier (1983)

• Wages (w):

- Cleaning of textiles: 1968-1989 Monatsgehälter von weiblichen Hilfsangestellten der Branche Kleider, Wäsche, Schuhe from HSSO G.15; 1989-1990 Monatsgehälter von weiblichen nicht selbständig Arbeitenden mit Berufslehre oder besonderen Kenntnissen HSSO G.15; 1960-1968 Monatsgehälter von weiblichen Hilfsangestellten der Branche Bekleidung, Ausrüstung from HSSO G.13

- Hair dressing, body care: 1971-1990 Monatsgehälter von weiblichen Angestellten mit Berufslehre der Branche Reinigung from HSSO G.15; 1968-1971 Monatsgehälter von weiblichen Angestellten mit Berufslehre der Branche Kleider und Ausrüstung HSSO G.15; 1960-1968 Monatsgehälter von weiblichen Angestellten mit Berufslehre der Branche Bekleidung, Ausrüstung from HSSO G.13

- Cleaning of real estate and inventories: 1968-1987 Monatsgehälter der männlichen Angestellten der Branche Reinigung, Kaminfegerei from HSSO G.14; 1987-1990 Monatsgehälter der männlichen Angestellten Baugewerbe/Zimmerei from HSSO G.14; 1960-1968 Monatsgehälter der männlichen Angestellten mit Berufslehre in den übrigen Industrien (Maler, Gipser, Schreiner, Elektroinstallateure, Autogewerbe sowie einzelne andere Gewerbezweige) from HSSO G.12

  - aggregation with 1985 employment weights from BFS BZ 1985
- Producer prices (P): from GDP by expenditure (BFS 01, 02, 03): Dienstleistungsexporte

Miscellaneous services (Income approach: projection with wL):

- Employment (L):
  - 1990 and 1985: from BFS 04
  - 1975: 1985 multiplied with 1975/1985 ratio from BFS, BZ 1985
  - 1965: 1975 multiplied with 1965/1975 ratio from BFS, BZ 1975
  - 1960-1965: constant growth with growth rate from 1965 to 1970
  - 1965-1975: geometric intrapolation
  - 1975 to 1985: geometric intrapolation
  - 1985-1990: intrapolation with constant growth rate and short-term fluctuations as in Meier (1983)
- Producer prices (P): from GDP by expenditure (BFS 01, 02, 03): Dienstleistungsexporte

Public services, education and research (Income approach: projection with wL):

- Employment (L):
  - 1990 and 1985: from BFS 04
  - 1975: 1985 multiplied with 1975/1985 ratio from BFS, BZ 1985
  - 1985-1990: intrapolation with constant growth rate and short-term fluctuations as in Meier (1983)
  - 1975 to 1985: intrapolation with constant growth rate and short-term fluctuations as SJ 1980/82/89, Beschäftigungsindex
  - 1960-1975: from Meier (1983)
- Wages (w):
  - 1974-1990: Wage expenditures of Confederation, Cantons, and Municipalities from SJ 1976-1994 divided by L (as above)
  - 1960-1974: from Meier (1983)
- Producer prices (P): from GDP by expenditure (BFS 01, 02, 03): Dienstleistungsexporte

Table A3: Benchmark comparison and time series projection for 1905 GDP per capita

		UK		USA		CH	
	Budget shares	Prices (pence)	Expenditure (pence)	Prices (pence)	Expenditure (pence)	Prices (pence)	Expenditure (pence)
Tea, coffee (1lb)	0.053	18.000	0.954	15.415	0.817	5.536	0.293
Sugar (1lb)	0.044	2.000	0.088	2.750	0.121	2.465	0.108
Bacon and sausage (1lb)	0.064	8.000	0.512	9.250	0.592	4.758	0.304
Beef and veal (1lb)	0.139	8.000	1.112	7.375	1.025	8.218	1.142
Pork (1lb)	0.052	8.000	0.416	6.500	0.338	8.520	0.443
Lamb and mutton (1lb)	0.054	8.250	0.446	7.375	0.398	8.218	0.444
Cheese (1lb)	0.027	7.000	0.189	10.000	0.270	8.607	0.232
Butter and margarine (1lb)	0.117	13.000	1.521	16.750	1.960	14.143	1.655
Potatoes (7lb)	0.057	3.000	0.171	7.000	0.399	3.330	0.190
Flour and meal (7lb)	0.060	9.000	0.540	12.500	0.750	11.505	0.690
Bread (4lb)	0.187	5.000	0.935	11.125	2.080	5.017	0.938
Milk (qt)	0.091	3.500	0.319	4.500	0.410	2.170	0.197
Eggs (doz)	0.054	12.000	0.648	14.400	0.778	10.298	0.556
Total	1.000		7.850		9.938		7.194
Benchmark comparison (average 1900-1910)							
Price level relative to UK			100		127		92
Exchange rate (per £)			1.00		4.86		25.17
PPP			1.00		6.15		23.07
Nominal GDP p.c. (avg 1900-1910)		£M.	47.8	$M.	310.6	SFr.M.	975.0
GDP per capita in 1905 PPP £		PPP £	47.8	PPP £	50.5	PPP £	42.3
Time series projection (average 1900-1910)							
Real GDP p.c. in 1990 GK $ (dd)			4521		4660		5825
Real VA p.c. in 1990 GK $ (dd)			4521		4660		5887
Real GDI p.c. in 1990 GK $ (sd)			4521		4660		4385
Real VA p.c. in 1990 GK $ (sd)			4521		4660		4502
Relative GDP levels		**UK/US**	**UK/CH**	**US/UK**	**US/CH**	**CH/UK**	**CH/US**
Benchmark comparison		94.7	113.1	105.6	119.4	88.4	83.7
Time series RGDP p.c. (dd)		97.0	77.6	103.1	80.0	128.8	125.0
Time series VA p.c. (dd)		97.0	76.8	103.1	79.2	130.2	126.3
Time series RGDI p.c. (sd)		97.0	103.1	103.1	106.3	97.0	94.1
Time series VA p.c. (sd)		97.0	100.4	103.1	103.5	99.6	96.6

Notes: The underlying consumption basket, budget shares, as well as British and American prices are from Williamson (1995). Swiss prices are from HSSO H.26 averages for Zürich, Bern and Basel. I excluded housing rents from the PPP consumption basket, because these are highly dependent on the sample cities and might not be representative for the national price level.

Figure A.1: Double-deflated value added and Real GDP by expenditure (1990=100)

Figure A.2: Nominal value added and nominal GDP by expenditure in Mio CHF