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The Adding-up Problem in the Computation of Aggregate Constant Price GDP

by

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The thrust of this note bears essentially on the adding-up problem in the current method of computation of aggregate constant price GDP. It does not suggest the adoption of new deflation techniques to solve the delemma outlined below, but only addresses the more limited question of which of the Canadian or the U.S. methodologies appear to be the more consistent in a restricted framework. It concludes that the procedure adopted in the U.S. is more "consistent" in that, unlike the Canadian procedure, it does not lead to double valuation of the same GDP components in any given year.

The aggregate constant price GDP figures are Laspeyres (base-year weighted) aggregates of component industries. The base-year is shifted every decade, the last one being 1981. The component industries' constant price GDP figures are obtained with the double-deflation method, whereby gross outputs and intermediate inputs are deflated by their respective price indices and real GDP is computed as the difference between the constant price value of outputs and the constant price value of inputs.

The adding-up problem stems from the methodology adopted at Statistics Canada which pursues the preservation of existing estimated growth rates of aggregates for past periods. As shown in the Appendix, choosing to maintain past growth rates produces the peculiar result that, for the decades preceding the last base year, constant price GDP figures for components do not add up to their aggregates for the same period. In the United States, the aggregates preceding the last base-year are simply recomputed by adding up the rebased components so that additivity is preserved. In this case, however, rates of growth of the rebased aggregates change each time the base year is shifted. Additivity and the preservation of past rates of growth of aggregates cannot be simultaneously obtained when base-year weighted Laspeyres indices are used for aggregation.

In the procedures followed in Canada, the components of any aggregate are valued in the relative price set of the new base-year when taken separately while, at the same time, they are valued in the relative price set of the previous base years when taken as components of the rebased aggregates. To use a spatial analogy, it is as if Americans, when assessing the Canadian production in comparison to that in the U.S. choose Canadian relative prices to evaluate production of components and U.S. relative prices to valuate aggregates. Clearly, they must choose U.S. relative prices throughout, while Canadians must use Canadian relative prices to make consistent, meaningful comparisons.

Turning back to the time space, it appears to be more consistent to evaluate both components and their aggregates through time with the same set of relative prices for any given year. Of course, the components may themselves be valued in the relative price set of the previous decades, translated into the last-base year constant dollar value, so that they would now add up to their corresponding rebased aggregates. This can be done, as shown in the mathematical derivations in the Appendix, by multiplying each past decade component by the aggregate Paasche price index. The procedure, however, though it preserves both past rates of growth of aggregates and additivity, does not preserve the growth rate of their components. We are thus back to the conclusion that the U.S. methodology is preferable from the poing of view of maintaining consistency of evaluation.

Appendix: Mathematical Derivations

The Laspeyres index of aggregate GDP, at time t based on year o (the reference year) set of relative prices, is given by

$$Q_{ot}(p_o) = \Sigma p_o q_t / \Sigma p_o q_o \tag{1}$$

where the q_t's are the component constant price GDP figures in year o prices (i.e., p_o=1).[1] The corresponding constant price value of the aggregate, V_{ot} is given by

$$V_{ot}(p_o) = \Sigma p_o q_t = V_{oo}(p_o) \,.Q_{ot}(p_o) \tag{2}$$

The three base-years actually choosen for computation of the input-output tables are t = 1961, 1971, 1981. We therefore have the following aggregate Laspeyres indices

$$Q_{61t}(p_{61}) = \Sigma p_{61} q_t / \Sigma p_{61} q_{61};\ 61 \le t < 71, \tag{3}$$

$$Q_{71t}(p_{71}) = \Sigma p_{71} q_t / \Sigma p_{71} q_{71};\ 71 \le t < 81, \textit{ and} \tag{4}$$

$$Q_{81t}(p_{81}) = \Sigma p_{81} q_t / \Sigma p_{81} q_{81}; \qquad t \ge 81, \tag{5}$$

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[1]. As the derivations of this appendix apply generally to all Laspeyres aggregation, not only the aggregation of real GDP, we have adopted here the usual notation of index number theory as if the q's could be measured in some physical units with corresponding prices p. We could have used instead the equivalent notation

$$p_k q_t = q_t(p_k)$$

indicating that "quantities" are measured in dollar units of year k. This notation has only been used when necessary as in equation 14.

The corresponding values of aggregates for these decades are V_{61t}, V_{71t}, and V_{81t}. To link these series, it has been decided to shift the base-year of the first two decades to the year 1981 while maintaining the relative price weights of each decade, that is to write

$$Q_{81t}\,(p_{61}) = \Sigma p_{61} q_t \,/\, \Sigma p_{61} q_{81}; \quad 61 \leq t < 71 \tag{7}$$

$$Q_{81t}\,(p_{71}) = \Sigma p_{71} q_t \,/\, \Sigma p_{71} q_{81}; \quad 71 \leq t < 81 \tag{6}$$

The indices given by (5) (6) and (7) take a value of one for $t = 1981$ so that they may be spliced. We may then write

$$V_{81t} = \sum p_{81}\; q_{81}\; Q_{81}(p_k) \tag{8}$$

where

$$\begin{aligned} k &= 1961 \qquad \textit{for } 1961 \leq t < 1971 \\ k &= 1971 \qquad \textit{for } 1971 \leq t < 1981 \\ k &= 1981 \qquad \textit{for } \; t \geq 1981 \end{aligned} \tag{9}$$

The series V_{81t} is the spliced series for $t \geq$ in 1961 in 1981 dollars but with relative prices corresponding to each decade. For $k = 1961$, for instance, we have

$$\begin{aligned} Q_{81t}\,(P_{61}) &= (\Sigma p_{61} q_t \,/\, \Sigma p_{61} q_{81})\;\; (\Sigma p_{61} q_{61} \,/\, \Sigma p_{61} q_{61}) \\ &= (\Sigma p_{61} q_t \,/\, \Sigma p_{61} q_{61}) \,/\, (\Sigma p_{61} q_{81} \,/\, \Sigma p_{61} q_{61}) \\ &= Q_{61t}\,(p_{61}) \,/\, Q_{6181}\,(p_{61}); \\ & \qquad 1961 \leq t < 1971. \end{aligned} \tag{10}$$

Since $Q_{6181}\,(p_{61})$ is a constant, it follows that $Q_{81t}\,(p_{61})$ and $Q_{61t}\,(p_{61})$ have the same rate of growth. Equation (10) is the formulation used to rebase the first decade's data into 1981 dollars while preserving its original rate of growth. This formula has a drawback however, since for $t < 1981$, the 1981 constant price aggregate value of output V_{81t} is

$$V^*_{81t} = \Sigma p_{81} q_t \tag{11}$$

which differs from the rebased value V_{81t} computed by (8). In other words, additivity breaks down. On the other hand if we use $Q_{81t}(p_{81})$ for all t then additivity is maintained for all years since V_{81t} is now defined by

$$\begin{aligned} V_{81t} &= \Sigma\ p_{81} q_{81} \cdot Q_{81t}(p_{81}) \\ &= \Sigma\ p_{81} q_{81}\ (\Sigma\ p_{81} q_t \,/\, \Sigma\ p_{81} q_{81}) \\ &= \Sigma\ P_{81} Q_t \end{aligned} \tag{12}$$

but, then, for $t < 1981$, the rate of growth of $Q_{81t}(p_{81})$ differs from the rate of growth of $Q_{81t}(p_{61})$, $(1961 \leq t < 1971)$ and $Q_{81t}(p_{71})$, $(1971 \leq t < 1981)$. For instance, over the period 1971 to 1980, one will generally have

$$Q_{81t}(p_{81}) = \frac{\Sigma p_{81} q_t}{\Sigma p_{81} q_{81}} \neq \frac{\Sigma p_{71} q_t}{\Sigma p_{71} q_{81}} = Q_{81t}(p_{71}) \tag{13}$$

except for $t = 1981$.

Looking now at individual components, we may see that changing the reference year for their prices does not change their rate of growth. Indeed, let

$$\begin{aligned} V_{it}(p_{71}) &= p_{71i}\, q_{it} \\ &\textit{and} \\ V_{it}(p_{81}) &= p_{81i}\, q_{it} \end{aligned} \tag{14}$$

then, for all time period s and t, we will have

$$\frac{V_{it}(p_{71})}{V_{is}(p_{71})} = \frac{q_{it}}{q_{is}} = \frac{V_{it}(p_{81})}{V_{is}(p_{81})} \tag{15}$$

This suggests that we maintain the relative price set of each decade for individual components as well as for aggregates by setting

$$V^*_{81it} = P_{k81}\ (q_{81}) = V_{it}\ (p_k) \tag{16}$$

where P_{k81} is the aggregate Paasche price index, with reference year k in 1981, defined as

$$P_{k81}\ (q_{81}) = \Sigma\ p_{81}q_{81}\ /\ \Sigma\ p_k q_{81} \tag{17}$$

Indeed, summing overall components v_{it}, we have

$$Z_{81t} = \frac{\Sigma p_{81}q_{81} \bullet \Sigma p_k q_t}{\Sigma p_k q_{81}} = \Sigma\ p_{81}q_{81} \bullet Q_{81t}\ (p_k) \tag{18}$$

which can be seen to be identical to the spliced series V_{81t} given by (8). The transformation (16) restores additivity and shows once more that both the components and their aggregate should be valued with the same set of relative prices. Nevertheless, this alternative solution is even more unsatisfactory as the rates of growth of individual components are no longer preserved. Indeed, we have for $1971 \leq s < 1981$ and $t \geq 1981$

$$\begin{aligned} \frac{V^*_{81it}}{V^*_{81is}} &= \frac{P_{8181}\ (q_{81})}{P_{7181}\ (q_{81})}\ \frac{P_{81i}\ q_{it}}{p_{71i}\ q_{is}} \\ &= \frac{P_{81i}\ /\ P_{71i}}{P_{7181}\ (q_{81})}\ \frac{q_{it}}{q_{is}} \end{aligned} \tag{19}$$

which will differ from $q_{it}\ /\ q_{is}$, except in the special case where the price increase for component i happens to be identical to the price increase for the aggregate.

To summarize, aggregates of past decades are actually rebased by multiplying them by the value of the corresponding aggregate Paasche index in the new base year. Obviously, rebasing all components by multiplying them by the same aggregate price index would maintain additivity. However, when rebasing as is now done, each component is multiplied by its own price index. This index generally differs from the aggregate Paasche price index by which these same components are implicitly multiplied as components of aggregate GDP and additivity necessarily breaks.

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