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Measure up: A Better Way to Calculate GDP

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EXECUTIVE SUMMARY

In the wake of falling commodity prices, the accuracy of GDP growth estimates in some emerging market economies have been subject to debate, in part because of the single-deflation method used to derive volume measures. A volume estimate of GDP is an essential measure of economic activity because it removes the effects of price changes. The *System of National Accounts 2008* (*2008 SNA)* recommends a technique called double deflation. In contrast, single deflation, the deflation with a single price index, is not recommended because it fails to capture important relative price changes that can be significant and may affect the accuracy of GDP estimates. How significant can the error be? This note breaks new ground by providing empirical evidence for the order of magnitude. The note approaches the question by applying single deflation to the GDP data of countries that use double deflation and comparing the results with the official data. Eight case studies are presented: Belgium, Brazil, Canada, France, Japan, Korea, the Netherlands, and the United States. We conclude that errors can be significant, although their direction cannot be predicted accurately, and they vary across countries and over time. We also apply the second-best method of single extrapolation to the same data and find that this method reduces the error in some but not all countries. We briefly outline a step-by-step approach toward adopting double deflation.

I. INTRODUCTION[1]

1. Volume measurement is a critical component of the national accounts compilation. To determine how many more (or fewer) goods and services can be purchased with a given increase in value, price and volume must be measured separately. A prominent example of a volume measure is GDP at constant prices, also referred to as real GDP, or value added in volume terms. There are broadly three techniques to derive volume measures for value added and GDP: double deflation, single extrapolation, and single deflation (direct deflation). Double deflation relies on independent deflators for input and output prices and tends to yield the best results. Single extrapolation refers to the use of a volume indicator to extrapolate value added and is considered the second best. Single deflation applies one deflator across the board and typically reduces the accuracy of the estimates.

2. While the bias[2] inherent in single-deflation methods is well known,[3] this note breaks new ground by investigating its possible order of magnitude. For a select group of countries that use state-of-the-art double-deflation techniques, we compare their official statistics with what would result if single deflation were applied. Based on the results, we demonstrate that the single-deflation methods can result in significant overall errors in the volume estimates. However, the differences can be both positive and negative, reflecting the respective movements of output and input prices. More specifically, when the output price moves faster than the input price, single deflation is expected to produce an overstatement of the volume estimate of value added growth. Conversely, when output prices move more slowly than input prices, GDP will be understated.

3. The error may be exacerbated during large commodity price changes. During times of major commodity price changes such as a sharp decline of the oil price, the single deflator method can produce significantly overstated GDP (and GDP growth) data in oil-importing countries. Conversely, in oil-exporting countries, single deflation could produce an understatement of GDP. Recently, criticisms about the accuracy of official GDP due to the inappropriate use of single-deflation methods have been raised for some emerging market countries by academics and journalists.[4]

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[1] The note benefited from suggestions of IMF staff, namely, Paul Cashin, Oya Celasun, James Daniel, Gian Maria Milesi-Ferretti, Gabriel Quiros, Johanna Schauer, Natalia Tamirisa, Bruno Versailles, and participants in the Statistics Department's Brown Bag series. James Chan contributed to developing the panel regression model in Annex 1. The authors also would like to acknowledge important contributions and comments on earlier drafts by external reviewers, namely, Rudi Acx, Hans De Dyn, Shuji Hasegawa, Young-Tai Kim, Hyeonyoeong Lee, Kwangwon Lee, Ronan Mahieu, Roberto Luis Olinto Ramos, Erich Strassner, Andreas Trau, and Piet Verbiest.

[2] In this note, "bias" refers the difference between inaccurate deflation methods (such as single deflation) and the ideal double deflation for measuring the real GDP (see Box 1).

[3] European Commission and others (2008), *2008 SNA,* paragraph 15.136.

[4] For China, see Herd (2016).

4. Double deflation is currently applied by virtually all advanced economies. Only a few G20 countries still use single deflation (Table 1).[5] Simulating double deflation for countries using single deflation is not feasible since it requires a significant amount of detailed data that is not readily accessible. Therefore, this note focuses on countries that use state-of-the-art deflation techniques and compares their official data with what would result if single deflation were applied.

Table 1. Deflation Measures Predominantly Employed in G20 Countries for GDP Volume Estimates

Country	Double Deflation/Year Introduced		Single Extrapolation	Single Deflation
Argentina			✓	
Australia	✓	1995		
Brazil	✓	1990		
Canada	✓	1950s		
China				✓
France	✓	1960s		
Germany	✓	1980s		
India				✓
Indonesia			✓	
Italy	✓	1980s		
Japan	✓	1978		
Korea	✓	2004		
Mexico	✓	1970		
Russia			✓	
Saudi Arabia			✓	
South Africa			✓	
Turkey			✓	
United Kingdom			✓	
United States	✓	1962		

Sources: Dissemination Standards Bulletin Board; country websites; and IMF staff; for Japan, Li and Kuroko, (2016); the United Kingdom, Bean, (2016).

Note: The information refers to annual GDP data and refers to the deflators applied to the major sectors of the economy according the available metadata.

[5] Table 1 shows the predominant deflation method for GDP volume estimates. In practice, countries use a mix of deflation methods. For example, India uses double deflation for agriculture and single extrapolation for electricity and some service activities. The United Kingdom currently uses double deflation only partially, as described in Bean (2016, Chapter 2).

II. OVERVIEW OF METHODS

A. Double Deflation

5. Double deflation means that outputs and inputs are deflated separately using relevant output and input price indices. The method is data intensive, as it requires data on a broad range of price measures for both outputs and inputs. To derive the volume estimates of inputs (more precisely, intermediate inputs or intermediate consumption), the compiler needs to derive price indices for the broad range of goods and services used in production. For example, if an establishment produces shoes, boots, bags, and coats, the value of output should be deflated by a compound deflator including all of these products. Similarly, intermediate consumption could include leather, glue, cardboard, and rubber, and the value of intermediate consumption should be deflated by a compound price index including those products (at least the most important ones). In other words, different price indices are needed because the goods and services included in intermediate consumption are not the same as the output and input, and output prices vary across industries. The more complex an economy, the more complex the compilation of input and output indices. In addition, intermediate inputs are measured at purchasers' prices whereas output is measured at basic prices or producers' prices (*2008 SNA*, paragraph 18.27).

6. Whereas price indices of goods may be readily available, price indices for services (for example, professional and business services, imported services) may not—and they may be difficult to compile. In this regard, many compilers—even compilers in countries with advanced statistical systems—may focus on using double-deflation techniques only for major industries.[6] These industries are usually primary producers or large, fairly homogenous manufacturing activities that may be susceptible to large fluctuations in input and output prices. For example, compilers may use double deflation for oil mining and refining or for major crops. In these cases, the prices of inputs may be readily available.

B. Single Deflation

7. Single deflation (sometimes also referred to as direct deflation) means that output and input prices are deflated with the same index. This process is used when output and input price indices are not available. Value added in volume terms is derived by deflating current value added directly by one price indicator[7]. Commonly, the output price is used to deflate gross value added

[6] Many countries use single deflation in the quarterly accounts. The use of such techniques—and the underlying assumption that the prices of outputs and inputs change at the same rate—may hold in the short term. Statistical techniques and data sources used for high-frequency estimates are not expected to be as rigorous as the ones used for annual estimates (Robbins and others 2010).

[7] Some countries use the consumer price index (CPI) as the single deflator. However, the CPI measures only the prices of goods and services purchased by domestic households for consumption. It includes prices of imports that

(continued)

because it is readily observable. The underlying assumption is that prices at which output is produced move at the same rate as prices at which intermediate inputs are acquired.

Box 1: A Conceptual Representation of the Bias Caused by Single Deflation

The size of the bias relates to the relative change of input and output prices. Value added in constant prices is the difference between output in constant prices and intermediate consumption in constant prices. When indices of output and input prices are available, double deflation can be used, as shown in equation 1.

$$\overline{VA} = \bar{O} - \overline{IC} = \frac{O}{D_O} - \frac{IC}{D_{IC}}, \qquad (1)$$

where VA represents value added, O refers to output, IC refers to intermediate consumption, and D represents the deflators. The bars on top of the variables refer to volume estimates (or constant prices).

If the respective prices are not available, and constant prices are derived by deflating value added with an output price (single deflation) as shown in equation 2,

$$\widetilde{VA} = \bar{O} - \ddot{IC} = \frac{O}{D_O} - \frac{IC}{D_O}. \qquad (2)$$

where $\widetilde{VA}$ and $\ddot{IC}$ denote the constant price estimates of value added and intermediate consumption using single deflation, respectively. The size of the bias can be expressed as the difference between (1) and (2):

$$\text{from (2):} \quad \frac{O}{D_O} - \frac{IC}{D_O} = \left(\frac{O}{D_O} - \frac{IC}{D_{IC}}\right) + \left(\frac{IC}{D_{IC}} - \frac{IC}{D_O}\right) \qquad \text{and replacing (1)}$$

$$\widetilde{VA} = \overline{VA} + IC\left(\frac{1}{D_{IC}} - \frac{1}{D_O}\right) = \overline{VA} + \boldsymbol{IC}\left(\frac{\boldsymbol{D_O - D_{IC}}}{\boldsymbol{D_{IC} * D_O}}\right) \qquad (3)$$

The resulting volume estimates of value added ($\widetilde{VA}$) will be biased with respect to the correctly derived one ($\overline{VA}$) as long as the prices of output and intermediate consumption differ ($D_{IC} \neq D_O$). The bias will be

$$bias = IC\left(\frac{D_O - D_{IC}}{D_{IC} * D_O}\right).$$

The volume of value added will be overstated when the bias is positive, and understated when the bias is negative. Overstatement will occur when $D_O > D_{IC}$, and understatement when $D_O < D_{IC}$. This implies changes in the level of real value added and explains effects on the dynamics of the volume. If prices of intermediate consumption are used for single deflation, the bias will be in the same direction but of higher magnitude.

C. Single Extrapolation

8. Single extrapolation means that output is deflated using the output price index. This method is considered an acceptable second best, provided GDP is compiled using an up-to-date

may not correspond to the prices of domestic output and it is measured at purchasers' prices, which may include indirect charges (not charged to the producer), distribution margins, and transport margins not related to production. The purchasers' price represents what the purchasers pay and may be different from what the producer charges for the output. Nevertheless, CPI components may be used to deflate some areas for production. If, for example, households and commercial entities are charged similar prices for electricity, the CPI component for electricity may be used to deflate electricity input prices for commercial entities. Other indices are needed for other areas of production.

base year (five years ago or less) to reflect the relative size of economic sectors. Value added is extrapolated from the base period using the growth of output in constant prices. Single extrapolation can be performed by using readily available volume indicators (such as a quantity index) or deflated values. The single extrapolation method can also be applied using volume of inputs. The assumption that the input-output technical coefficients do not change is likely to hold in the short term, as changes in the technical coefficient are generally associated with changes in technology, which may take some time to introduce. Regular benchmark updates are particularly relevant when this method is used. For example, if a new machine is incorporated in the production process, which reduces the use of oil, single extrapolation will overestimate intermediate consumption and then underestimate value added.

III. DOUBLE VS. SINGLE DEFLATION: SIMULATION

9. We simulate the effects of single deflation for countries that use double deflation in their official GDP estimates. The reverse—simulating double deflation for countries that apply single deflation—is not feasible because the additional detailed information is generally not available. We focus on countries that use state-of-the-art deflation techniques and compare their official data with what would result if single deflation were applied.

10. We selected eight countries with sound deflation methods and data availability by economic activity. The selected countries are Belgium, Brazil, Canada, France, Japan, Korea, the Netherlands, and the United States. These countries show varying degrees of market openness, changes in the terms of trade, and GDP share of service activities since 2000 (see Appendix Table 1.1), three factors that may influence the size and direction of bias of single-deflation methods. We worked in close collaboration with the statistics agencies of these countries, and some provided us with detailed (unpublished) data on output, intermediate consumption, and gross value added by economic activity both at current prices and in real terms.[9] We consulted with members of the Intersecretariat Working Group on National Accounts, the interagency group that oversees the methodological development and implementation of the *System of National Accounts,* currently chaired by the IMF. This research has also benefited from comments and consultations with members of the Advisory Expert Group on national accounts.[10]

[9] For the European Union countries, we extracted the data from the Eurostat database of national accounts. For Japan, Korea, and the United States, we collected the data from the website of the compiling agencies. Brazil and Canada submitted detailed data on output and intermediate consumption. For each country, we conduct the exercise at a minimum detail of two-digit level of the *International Standard Industrial Classification of All Economic Activities (ISIC) Rev. 4*.

[10] In accordance with the mandate from the United National Statistical Commission, the Advisory Expert Group is assisting the Intersecretariat Working Group on National Accounts in resolving issues on the *System of National Accounts 2008 (2008 SNA)* research agenda, the implementation of the *2008 SNA*, and emerging research issues. The Advisory Expert Group comprises internationally recognized experts in the area of national accounts as well as the United National Statistical Commission, the IMF, OECD, the World Bank, and Eurostat.

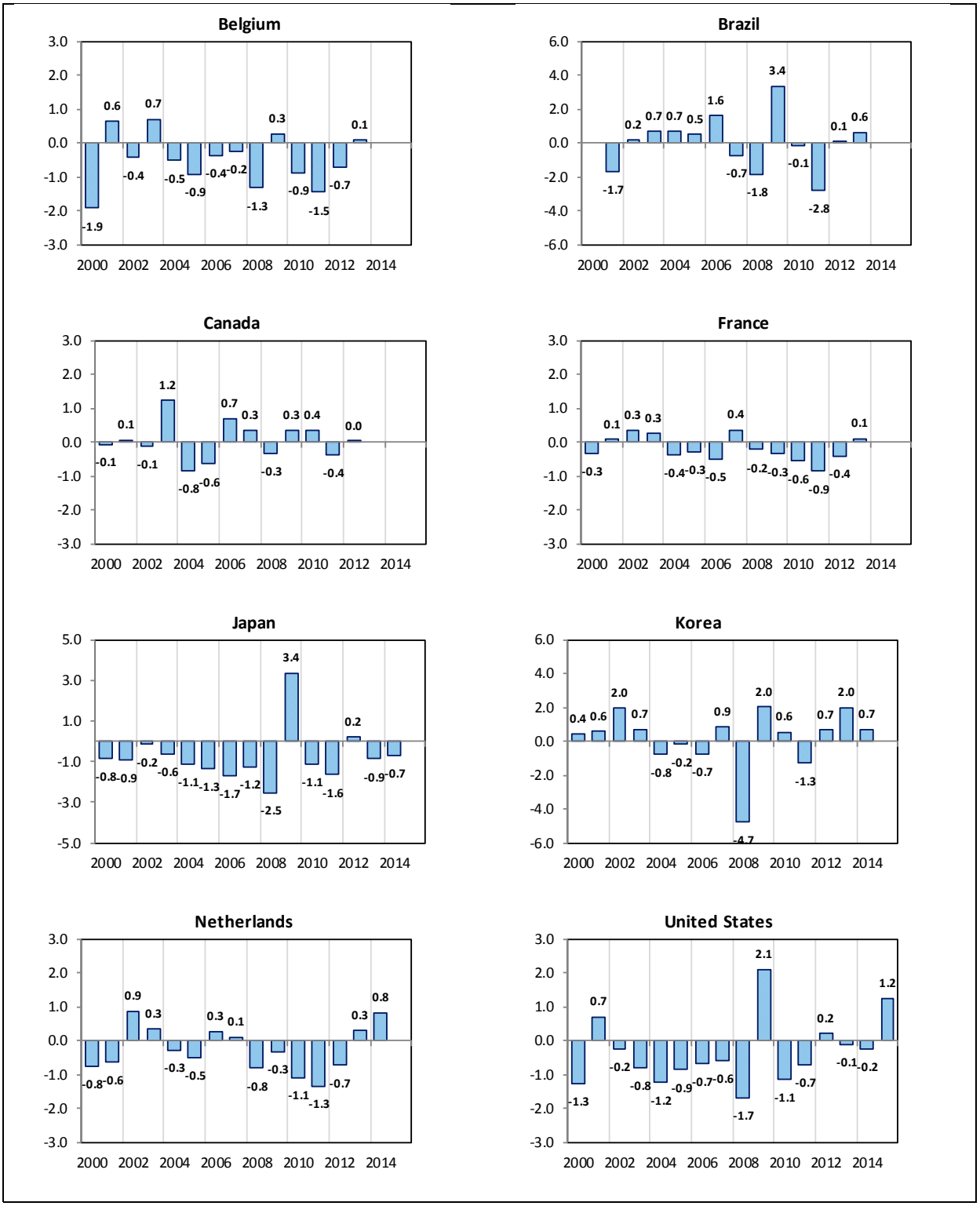
11. Our simulation of single deflation consists of using the output price index to deflate directly the value added at current prices by economic activity. The output price index is the implicit price index of output, derived as the ratio between output at current prices and output in volume terms. As for the gross value added at current prices, we consider the difference between output and intermediate consumption at current prices (that is, the official estimate of gross value added at current prices). By dividing gross value added at current prices with the output price index, we obtain a volume estimate of gross value added based on single deflation. Subsequently, the single-deflation estimates of gross value added for each economic activity are aggregated at the total economy level. To measure the impact of single deflation, we calculate the difference between the single-deflation estimate and the official estimate of total global value added. The database will be published separately.

12. Our results show that single deflation can introduce a significant error in the gross value added growth. Figure 1 shows the differences with the official growth estimates for the eight countries in the years 2000–15. A positive value indicates that the single-deflation estimate overstates the official estimate. A negative value indicates that the single-deflation estimate understates the official estimate. The various panels of Figure 1 highlight that for some years, single deflation deviates from the official estimates by up to 3–4 percentage points. Furthermore, the differences over time appear to be autocorrelated for the majority of countries (that is, a positive difference is likely to be followed by another positive difference, and vice versa). Finally, some countries show large differences during 2008–09, the years of the global financial crisis (in particular, Japan, Korea, United States).

13. The single-deflation estimates lead to a systematic underestimation of GDP growth in commodity importers during the global commodity price boom. Figure 1 also suggests that for commodity exporters, particularly Brazil and Canada, the use of single deflation tends to overstate GDP growth during the period of the commodity price boom from early 2000 until the global financial crisis. These trends are reversed when commodity prices begin to fall.

Figure 1. Difference between Single Deflation and Official Estimates Using Double Deflation

(Value added growth, percentage points)



Sources: Country websites; and IMF staff estimates.

14. The direction of errors reflects the different movements of output and input prices experienced in these countries. Table 2 presents summary statistics (mean, absolute mean, standard deviation, minimum, and maximum) of the differences between single deflation and the official estimate. On average, single deflation produces an understatement for five countries (Belgium, France, Japan, Netherlands, United States) and an overstatement for three countries (Brazil, Canada, Korea). In absolute terms, the largest impact of single deflation is noted for Japan, Korea, and Brazil. The effect on European Union countries is relatively small. In particular, France and Canada show the smallest differences with respect to the official estimates (0.36 percent and 0.41 percent, respectively).

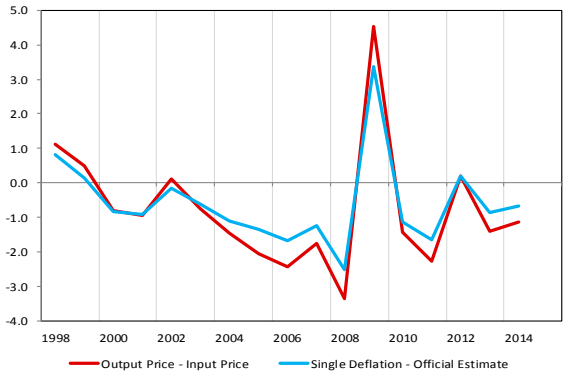
Table 2. Summary Statistics on the Difference between Single Deflation and Official Estimate of GDP (Percentage points)

Country	Sample Period	Mean Difference	Mean Absolute Difference	Standard Deviation	Minimum Difference	Maximum Difference
Belgium	2000–13	–0.50	0.75	0.77	–1.92	0.70
Brazil	2001–13	0.04	1.14	1.58	–2.79	3.36
Canada	2000–12	0.05	0.41	0.55	–0.84	1.22
France	2000–13	–0.20	0.36	0.37	–0.85	0.36
Japan	2000–14	–0.74	1.21	1.30	–2.51	3.36
Korea	2000–14	0.18	1.21	1.69	–4.75	2.02
Netherlands	2000–14	–0.25	0.61	0.67	–1.33	0.86
United States	2000–15	–0.33	0.86	0.99	–1.68	2.09

Source: IMF staff estimates.

15. In Brazil and Japan, the large increase of output prices relative to input prices in 2009 would lead to a growth bias of 3.4 percentage points when using single deflation. Overall, the impact of single deflation on growth depends heavily on the developments of producer prices, consumer prices, and external trade prices. Figure 2 illustrates this point using data from Japan. The opposite effects would have happened for Korea in 2008, where single deflation would have produced an understatement of GDP growth by 4.8 percentage points.

Figure 2. High Correlation between Single-Deflation Bias and Differential between Output Prices and Input Prices—The Example of Japan



Source: IMF staff estimates.

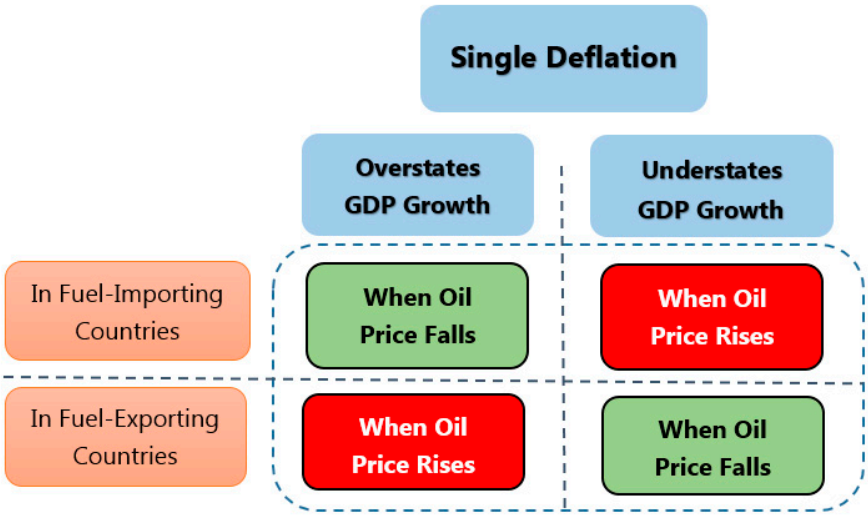
16. Comments received from the statistical agencies whose data were used for this study indicate a variety of causes that explain short- term differences between input and output prices.[11] In Belgium, the size of the GDP bias depends on the weight of the industry where single deflation is applied, and the size of its output-input ratio. The closer the ratio is to 1, the higher the impact of the difference between input prices and output prices on real GDP. In Japan, single deflation produces a large (positive) bias in 2009 because single deflation does not capture the sharp fall in crude oil prices in that year. More generally, differences between export and import prices is not captured by the single-deflation method. In Korea, input prices are affected by movements in the exchange rate; in 2008, the sharp depreciation of the Korean won-US dollar exchange rate led to a sudden increase in input prices. This depreciation explains why single deflation produces a large understatement of Korean growth in 2008 (Figure 1). This may apply for large importers of raw materials generally (Korea's imports of raw materials are about 21 percent of GDP and total imports are about 41 percent of GDP during the time period). In the Netherlands, volatile prices lead to large differences between single deflation and double deflation. Applying single deflation to services such as trade, government, and education is particularly misleading. In the United States, single deflation can produce misleading results when economic growth is changing rapidly. In such situations, substantial changes in prices for intermediate inputs may not be immediately passed through.

17. The single-deflation error is highly correlated with changes in the commodity terms of trade and exchange rates, which can drive large relative changes in the prices of outputs versus inputs. For instance, in economies that are net oil importers, an increase in global oil prices would tend to raise input prices more than output prices. Using our simulation results for the eight countries, we estimated a panel regression model to correlate the estimation error of single deflation with country-specific commodity import and export prices and the nominal effective exchange rate (Annex 1). The estimated panel model shows that an increase in the commodity import price (which increases the input prices) results in an understatement of GDP growth using single deflation.[12] On the other hand, an increase in the commodity export price (which increases the output prices) produces an overstatement of GDP growth using single deflation. Finally, a currency appreciation leads to an overstatement of GDP growth using single deflation because the strongest currency improves the terms of trade, and consequently increases the output prices relative to input prices (the opposite happens in cases of depreciation). Figure 3 illustrates these findings.

[11] This paragraph summarizes comments received by staff from the National Bank of Belgium, Cabinet Office of Japan, Bank of Korea, Statistics Netherlands, and the U.S. Bureau of Economic Analysis.

[12] The purpose of the panel model is to verify that the single deflation bias for the eight countries was related to changes in input and output prices that occurred during the sample period. The panel framework is simply used as a tool to calibrate the size and sign of the different drivers of the estimation error across countries. The model coefficients should not be used to predict the bias in other years, and neither for other countries that are not included in the sample.

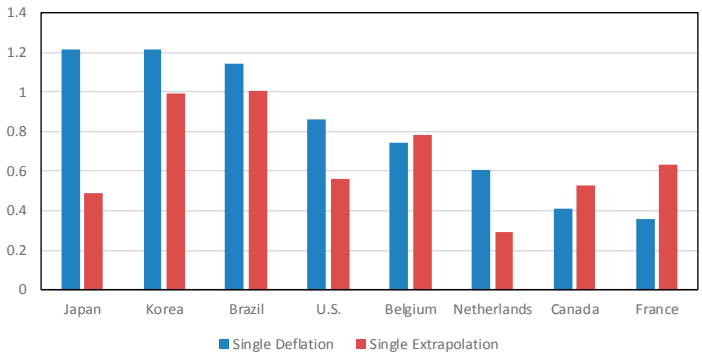
Figure 3. Single Deflation, Changes in Fuel Prices, and the Direction of GDP Bias



Source: IMF staff.

18. Our simulations confirm only partially that single extrapolation produces more accurate results than single deflation. The single-extrapolation volume measure of gross value added is obtained by moving forward GDP at current prices from the base year using the output volume indicator. Figure 4 shows that single extrapolation reduces the difference with the official estimate for five out of eight countries. The reduction is particularly evident in Japan, where the mean absolute difference using single extrapolation shows a dramatic reduction compared with single deflation (0.49 vs. 1.21 percentage points). However, France shows a substantial increase of the error using single extrapolation, although it remains well below the size of the error from single deflation identified for other countries. Comments received from statistical agencies indicate that, in general, single extrapolation provides better results than single deflation, as the assumption of a constant input-output ratio in volume terms tends to hold in the short term.

Figure 4. Mean Absolute Difference of Single Deflation and Single Extrapolation
(Percentage points)



Source: IMF staff estimates; for sample periods see Table 2.

IV. MOVING TOWARD DOUBLE DEFLATION

19. The adoption of double deflation requires the development of a number of indicators. The IMF has provided advice to many countries, and this section summarizes some key steps to introducing double deflation, along with some observations about resource implications and timing. As a first step, the authorities should assess the possible direction and size of the bias introduced by single deflation. This first exercise would provide a rough idea of the economic activities most likely affected by the use of single deflation and economic sectors. As noted, moving from single deflation to single extrapolation may be a useful intermediate step and it does not require new data, but rather a change in the estimation procedure from deflating value added to deflating output and extrapolating the value added.

20. In the medium term, more in depth work would be required to address other methodological issues and new data sources. Generally, key medium- and longer-term issues are an update of the benchmark estimates to reflect the relative size of the various economic sectors, the development of price indices for outputs (for example, producer price index) and inputs (for example, import price indices), and generating appropriate independent deflators for output and intermediate consumptions by economic activity.

21. The resource implications for introducing double deflation depend on the data gaps and the needs for updating the national accounts framework. Updating the national accounts benchmarks is resource intensive but should be part of the regular compilation cycle. The establishment of new price indices would require additional human resources as well as new surveys. Starting up new price indices may take one or two years. The adoption of double deflation would require additional resources to maintain the compilation of appropriate output prices and intermediate consumption prices. Procedures must be adjusted and additional calculations included, which entail supplementary validation and additional analytical tables. Ideally, the historical series should be revised backward to avoid a break in the GDP series.

22. Revisions to the GDP should be communicated to the users before the new estimates are made public. Given the technical nature of the issue of deflation, a few illustrative examples should be provided to help users understand why double deflation better mirrors the economic reality. It may also be advisable to explain that the development of new indicators (deflators) adds to the serviceability of economic statistics.

V. CONCLUSIONS

23. This note illustrates that estimates in the annual national accounts (annual GDP or gross value added) using the single deflation method produce significant errors. While the *System of National Accounts 2008* recommends the use of double deflation rather than single deflation, this note is the first to demonstrate the materiality of the bias introduced when single deflation is used. Eight country cases are presented to establish that single deflation can produce a large bias of GDP growth rates.

24. We show that the bias can be exacerbated during large commodity price or exchange rate changes. For example, during times of major commodity price changes such as a sharp decline of the oil price, the single deflation method can produce significantly overstated GDP (and GDP growth) data in oil-importing countries. Conversely, in oil-exporting countries, single deflation could produce an understatement of GDP.

25. Regular updates of the base year are required in order to maintain the accuracy of the volume estimates of GDP. In addition to the appropriate deflation method, regular updates at intervals of (at least) five years are required to ensure that that weights of the constant price series are representative.

26. The main recommendation is that countries should take steps to adopt double deflation. When this is not realistic in the short term, countries can explore whether single extrapolation may constitute a useful improvement with relatively minimal technical requirements. Single extrapolation can be an interim solution when input-output volumes move slowly over time. Countries should investigate the changes in the input-output structure in the recent past and its likely evolution in the future. Indeed, our research suggests that single extrapolation does not always improve the result. Double deflation should be adopted in particular for those activities with large fluctuations of input-output prices and volumes over time.

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ANNEX I.

Annex Table 1.1. Openness, Terms-of-Trade Changes, and Service Share in G20 Countries*

Country	Trade in Percent of GDP (average 2000–14)	Range of Terms of Trade during 2000–14 (maximum *minus* minimum)	Change of Share of Services in GDP between 2000 and 2014 (in percent)
Argentina	32.79	41.72	–6.2
Australia	41.23	23.79	–0.1
Belgium	148.56	4.86	6.3
Brazil	25.64	28.02	3.3
Canada	68.00	20.71	5.4
China	50.05	18.62	8.2
France	54.85	6.12	4.6
Germany	73.98	9.25	1.0
India	42.53	32.55	8.8
Indonesia	55.78	13.21	0.4
Italy	51.75	9.20	4.3
Japan	28.40	33.43	4.7
Korea	83.65	15.06	1.9
Mexico	57.31	17.98	2.0
Netherlands	131.89	3.52	4.2
Russian Federation	55.20	55.18	5.1
Saudi Arabia	80.44	62.43	–0.9
Turkey	51.12	8.96	5.5
South Africa	58.61	12.04	3.2
United Kingdom	56.77	3.67	6.3
United States	26.75	12.70	2.0

Source: IMF staff estimates.
* Indicators that drive possible divergences between input and output prices associated with larger errors of GDP estimates when single deflation is used.

Annex Table 1.2. A Panel Regression Model to Correlate the Single Deflation Errors with Key Drivers of Terms of Trade

In this research, we observed that the size and direction of the GDP estimation error due to single deflation depend on the relative changes in input and output prices. A sizable fraction of relative changes in input and output prices reflect, in turn, changes in global commodity prices and exchange rates. To quantify this relationship, we estimate a panel regression model using three indicators that affect the terms of trade of countries: (1) country-specific commodity import price index, (2) country-specific commodity export price index, and (3) nominal effective exchange rate (NEER). The country-specific commodity price indices are based on Gruss (2014); the NEER is taken from the IMF's International Financial Statistics database.

A balanced panel is available for the eight countries analyzed from 2001 to 2012. The regression equation includes country fixed-effects and is estimated using the least squares method. The three estimated coefficients are highly significant, and the model fit is good (the model can explain more than half of the variation in the single deflation error). The signs of coefficients are in line with expectations. In particular, we note that for the countries and sample period examined:

- A 1 percentage point increase in the commodity import price (for example, which increases input prices) causes, on average, an understatement of GDP growth by 0.07 percentage points.
- A 1 percentage point increase in the commodity export price (for example, which increases output prices) leads, on average, to an overstatement of GDP growth by 0.02 percentage points.
- A 1 percentage point in the NEER (for example, currency appreciation) leads, on average, to an overstatement of GDP growth by 0.08 percentage points.

Dependent Variable: GDP Estimation Error due to Single Deflation (Growth Differential in Percentage Points)
Method: Panel Least Squares
Sample: 2001 2012
Periods included: 12
Cross-sections included: 8
Total panel (balanced) observations: 96

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000171	0.000720	0.237254	0.8130
DLOG(Commodity Import Price)	-0.065010	0.010837	-5.998611	0.0000
DLOG(Commodity Export Price)	0.023978	0.005725	4.188237	0.0001
DLOG(Nominal Eff. Exch. Rate)	0.079016	0.019383	4.076628	0.0001
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.520817	Mean dependent var		-0.002645
Adjusted R-squared	0.464442	S.D. dependent var		0.011301
S.E. of regression	0.008270	Akaike info criterion		-6.644898
Log likelihood	329.9551	Hannan-Quinn criter.		-6.526126
F-statistic	9.238510	Durbin-Watson stat		2.342848
Prob(F-statistic)	0.000000			

The regression results imply that the single-deflation error associated with given change in commodity import prices is about four times as large as the error associated with an equally-sized change in commodity export prices. The relatively larger impact of commodity price changes on the error reflects that the bulk of the countries in the sample are regression net commodity importers, where commodities tend to account for a larger share of inputs than they do for outputs.

It is important to clarify that these model results cannot be generalized. The estimated coefficients capture the average effect of the commodity import and export prices and of exchange rate movements in explaining the single deflation bias estimated for the eight countries in the sample. By no means the model results can yield precise predictions of the error for any single country.