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REASSESSING CHINA'S GDP GROWTH PERFORMANCE: AN EXPLORATION OF THE UNDERESTIMATED PRICE EFFECT*

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ABSTRACT

Instead of searching for alternative indicators, this study accepts the official nominal GDP statistics at face value and reassesses real growth by investigating the underlying price effect that is intrinsic to and coherent with the national accounts. Based on reconstructed national input-output tables in time series, we address two major biases that may have significantly distorted the official growth estimates of China, i.e., a single-deflation bias caused by discrepancies between input and output prices and an aggregation bias that is caused by a constant-price value aggregation problem. Compared to the smooth official growth rates, our procedures have exposed more volatile movements of, and greater impacts of external shocks on the Chinese economy. We estimate an annual growth rate at 8.3 percent for the entire reform period 1978-2018, which is 1.2 percentage points below the officially claimed rate of 9.5 percent. In real terms, this downward adjustment means that until 2018, China's accumulated national income over the past forty years could be 36 percent smaller than that suggested by the official data.

Key words: National accounts; supply-use and input-output tables; producer and purchaser price indices; implicit value-added price index; single and double deflation methods; constant-price value and Törnqvist index aggregation approaches

JEL classification: C82, E01, E31

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1. INTRODUCTION

Few would disagree that the world could not afford misreading the real growth performance of China, now the world second largest economy if measured in market exchange rate and the largest if in PPP terms, nevertheless the long debate about the quality of China's GDP statistics has remained inconclusive. While most of researchers have been continuously showing that officially reported growth estimates have covered up external shocks and smoothed out volatilities, hence likely exaggerating the reality, some argue that they are reasonably reliable and even improving over the past decade. Yet, among those who believe that the official data do suffer from synthetic smoothing and upward bias have not reached a consensus on the degree of the problem and the period(s) it prevailed.

The major obstacle to a convincing conclusion of the debate is a lack of a theoretically-sound common ground not only for researchers to effectually communicate with each other, but more importantly for productive discussion between researchers and official statisticians who are responsible for constructing the data, which is deemed the best way to improve official statistics. This situation is attributable to a widely used physical indicator approach that relies on various indicators in volume measures from the production side, the expenditure side, or mix of the both sides to gauge the real growth. Although some indices based on such an approach may better capture the real changes of the economy than the official data in certain time and space, as alleged by their users, they cannot be easily translated into the system of national accounts that together with its coherent price indices to generate the real value added.

Given the theoretical nature of the problem, a common ground for constructive discussion is inevitably and essentially the system of national accounts. However, the key impediment to having a national accounts-based growth assessment is lack of systemic information on prices notwithstanding the quality of the national accounts. Indeed, to those early researchers who proposed the upward-bias hypothesis in the 1990s, the physical indicator approach was to bypass the official problematic price data whose problems could not be easily solved mainly because of the non-transparent procedures of official data construction, besides the inadequacy of the data. Despite various credible indicators that have been proposed to challenge the official growth estimates, it is nonetheless this approach that has engaged researchers in constantly seeking better indicators and distracted them from a *systematic investigation* in the underlying price effect.

With more information on Chinese national accounts and prices today contrasted to the past, especially to the period prior to the 2000s, we make the first attempt to propose a national accounts-based reassessment of the official growth statistics for the entire reform period from 1978 to 2018. Using the official GDP accounts published annually, full input-output tables released every five years from 1987 to 2017 together with a reconstructed material product system (MPS)-concept table for 1981, and price data of various official sources as the raw data, we first construct China's full national accounts for economy-wide 37 industries in time series following the standard procedures and a matching series of producer price indices, then conduct a double deflation procedure at the industry level, correcting a long-standing single-deflation bias embedded in official estimates, and we finally use a Törnqvist index approach to the aggregation problem to obtain a real growth rate for the whole economy.

These procedures have not only exposed more volatile movements and greater impacts of external shocks, but also slower growth, compared to the official data. Our estimation of China's GDP growth rate is at 8.3 percent per annum for the period 1978-2018, which is 1.2 percentage points below the officially claimed rate at 9.5 percent.

This paper proceeds as follows. Sections 2 is devoted to a background to the research problem through a literature review highlighting main conceptual issues that facilitate our quest. Section 3 explains our data problems and procedures of constructing China's input-output tables in time series and matching producer price index matrices. Section 4 focuses on the methodological problems of deflation and aggregation. It first explains why the double-deflation approach rectifies distortions caused by the single-deflation method and then why the constant-price value aggregation approach should be replaced by a Törnqvist index-based aggregation approach. Section 5 discusses our estimates in comparisons to those using different deflators, deflation methods, and aggregation approaches. Section 6 briefly concludes the paper with some caveats.

2. A Review of the Literature

The physical indicator approach, which is based on indexing a specific economic activity or its output in volume movement, such as goods manufactured, energy consumed or freight handled in their physical units, is a "classic approach" in measuring changes of the real output when price data are generally unavailable or unreliable. It was particularly used by western economists to gauge the real growth performance of centrally planned or command economies, such as the former Soviet Union, other former Eastern Bloc countries, and the pre-reform China where prices were heavily manipulated to serve the growth targets of the planning authorities and the problems they caused inevitably, hence meaningless from a cost perspective (Gerschenkron, 1951; Kaplan and Moorsteen, 1960; Bergson, 1961; Chao, 1965; Field, 1970). In Gerschenkron's view, there is a tendency for official growth rates under central planning to contain upward bias not only because of methodological deficiencies, such as the improper use of earlier weights in output indexing, known as the Gerschenkron effect, and the mishandling of the prices of new products, but also because of political interferences in the data generating process (Gerschenkron, 1947).

It is worth a quick glance at the studies using the physical indicator approach to assess Chinese official output statistics before the transition of the Chinese statistical system from the Marxist MPS to the international standard of the system of national accounts (SNA) in the mid-1990s along with the adoption of the "socialist market economy". Among a few pioneers in the 1960s, Liu and Yeh (1965) were the first researchers who used major products as physical indicators to assess Chinese official gross output data assembled in the MPS concepts and to construct China's SNA-type national accounts for the period 1952-1957.[1] Over the following two decades, researchers were painfully caught in between the West's high demand for China's economic reality and highly deficient and problematic data. Along with a group of enthusiastic scholars who devoted themselves entirely in assessing China's growth performance, scholarly works by Rawski (1973, 1980) and Field (1970, 1973 and 1980) should have deserved most credits even though they did not come out with a heavy criticism on the official statistics.

China's transition to the "socialist market economy" and to a SNA-compatible statistical system greatly exposed the authorities' weakness in measuring prices if not unwillingness in openly reporting them. Earlier in the late 1980s, Field (1988) identified flaws in farm output data that did not distinguish current and constant prices, whereas Perkins (1988) suspected that the Chinese price system could be a major barrier to our understanding of China's growth performance. In the early 1990s, Field (1992) empirically speculated that the official growth estimates might contain upward bias, whereas Rawski (1993) came out denouncing Chinese price data after a careful investigation, an endeavor that completely altered his own view about

[1] Liu and Yeh (1965) estimated China's GDP growth at 6.2% per annum in 1952-1957, compared to then the official estimate of gross output value at 10.9% (NBS, 1959) and GDP at 6.7% after a claimed full transition to SNA (NBS, 2019). For a reference, Maddison and Wu (2008)'s estimate is at 5.8% for the same period.

the quality of Chinese industrial growth statistics in his 1980 article. This is an influential study that convinced many researchers to bypass official price statistics and focus on physical indicators from the 1990s through the 2000s.

China's reported superfast GDP growth in the early to mid-1990s did not appear to be complying to its unprecedented price soar.[2] While some researchers speculated mishandlings of constant and current prices at the enterprise level (Woo, 1996), some proposed various physical indicators to test the upward-bias hypothesis either for the whole economy or its subsectors, ranging from energy consumption (Adams and Chen, 1996; Rawski, 1993), food consumption (Garnaut and Ma, 1993), industrial products (Wu, 1997), farm products (Maddison, 1998), to numbers employed in services (Maddison, 1998). All these studies provided evidence in favor of the upward-bias hypothesis. For the total economy over the period 1978-1995, compared to the official growth rate of 9.8 percent per annum (NBS, 2019), alternative estimates vary from 4.8 (Adams and Chen, 1996) to 7.5 percent per annum (Maddison, 1998). For the industrial economy, after revising his earlier work using over 200 major industrial products aggregated by the official input-output table weights, Wu (2002) arrived at a growth rate of 8.7 percent per annum for the period 1978-1997 instead of 12 percent as officially claimed.

Physical indicators by nature could hardly achieve consensus among researchers. Controversies arose after Rawski (2001)'s speculation that China's actual growth over the period 1997-2001 or in the wake of the Asian financial crisis was no more than one-third of the official claim (7.7 percent per annum according to the latest official statistics; NBS, 2019) or even around zero based on his selected indicators of energy, transport and retail sales. However, using a principal component approach to 15 series, ranging from grain output to long-distance calls, Klein and Ozmucur (2002/2003) maintained that official data are generally trustworthy. This was disagreed by Young (2003)'s work that, using alternative deflators, alleged that China's growth rate could be overstated by 2 percentage points per annum over the period 1978-1998. Yet, Chow (2006) heavily criticized Rawski and Young with his opposite findings based on a basket of 23 industrial products, priced and weighted to his choice.

[2] The growth rate in 1992-96 was about 12% per annum with its peak at 13.3% in 1992 and the inflation was nearly 14% per annum with its peak at 20.6% in 1994, unprecedented since 1952 (NBS, 2019).

Rawski's 2001 article also advocates that for a special macro event, either a market shock or an institutional reform, carefully examining the discrepancy between an official estimate and an alternative indicator for the time point of the event could be much more meaningful than observing the trend performance of a prolonged period. Indeed, by investigating the newly revised growth statistics since 1992 following China's 2004 Economic Census, Wu (2007) finds that the 7.8-percent rate for 1998, slightly missing the government's 8-percent growth target, was unreasonably, and of course unprofessionally, left intact. By extending the work in his 2002 article, Wu shows that China's growth in 1998 was merely 0.3 percent as Rawski speculated, supporting the suspicion that the official estimate was falsified to cover up the severe downfall of the economy instigated by the Asian financial crisis.

In the most recent decade, alongside the increasing integration of the Chinese economy with the world economy, the interest in China's real growth performance began shifting from trends to time patterns of a period concerned, emphasizing differences in shocks, volatility, and cyclicality between official statistics and alternative physical approaches. Yet, empirical results still disputed. Using a more sophisticated index construction method, Wu (2013 and 2014a) enhanced the findings in Maddison and Wu (2008) and confirmed that the upward bias was mainly caused by synthetically smoothed official data that covered up external shocks and reduced volatility. Later, Nakamura et al. (2016), using an Engel-curve approach to analyzing the behavior of food stuff and other consumption goods, alleged that "Chinese official GDP statistics present a smoothed version of reality", hence causing a substantial loss of information. To the contrary, Fernald et al. (2015), using a principal component approach, and Clark et al. (2020), innovatively exploring a relationship between nighttime lights and China's aggregate growth, claimed that official GDP data had become more informative since the global financial crisis in 2008.

While these physical indicators-based results appear to be hardly reconcilable, business analysts have begun questioning how China's apparent cyclical growth performance in nominal terms was translated into an increasingly smooth growth path in real terms during the post Global Financial Crisis (for a recent example see Wright and Rosen from the Rhodium Group, 2019). Observers exploring the smoothing hypothesis have increasingly used the Keqiang Index or its variants relying on the mix of physical and value indicators.[3] This has brought back

[3] The Li Keqiang index was introduced by *The Economist* ("'Keqiang Index' Falls in May", Issue of December 9, 2010) following a disclosed conversation between Li Keqiang, then the Party Secretary of Liaoning Province, and a US ambassador about the unreliability of the official GDP figures. It is a composite of railway

the price problem that was deliberately bypassed by the physical-indicator users from the very beginning of the inquiry. Chen et al. (2019) should be complemented not only for being the first one working on China's growth performance in nominal terms, but more importantly for exposing us to the underlying and long ignored price issues. When facing the deflation problem, the authors have no choice but use official implicit GDP deflators to deflate their nominal estimates of both production and expenditure sides. They claim that the official growth rate could be overstated by about 2 percentage points per annum from 2008 to 2016, yet the so-estimated real growth path is inescapably a smooth one, which explains why reviewers of this study call for an investigation on the role of prices.[4]

Conceptually, it is indeed the role of prices, or more precisely, the relative costs of factors and intermediate inputs across industries that boil down the issue to the very fundamentals of economics, that is, growth is created while resources move in line with their nominal returns consisting of both price and real effects. A proper price investigation, if focusing on the production side of the economy, obliges a system that coherently integrates the costs paid to all inputs by productive activities. This is the "current production accounts" of the national account systems in time series, which, in our view, is essential to make the communication on the reliability of Chinese official growth figures amongst researchers and between researchers and official statisticians not only possible but also constructive. This motivates our mission in this study.

3. Reconstruction of National Accounts and Deflators

Strategy to deal with data problems

Despite three decades of China's statistical transition from the MPS to the SNA regime, there are still no complete national accounts in Chinese official statistics that satisfy the international standards and are available annually. We rely on two primary sources of the data in this study, namely Chinese Input-Output Tables or CIOTs and China Statistical Yearbooks or CSYs. Both are compiled and provided by China's National Bureau of Statistics (NBS) with

cargo volume, electricity consumption and bank loans without a sound theoretical ground and reasonable weights. Also see Nakamura et al. (2016) for a discussion of the Li Keqiang index.

[4] When discussing the potential problems of official deflators (see the discussion section at the end of Chen et al. 2019, participated by Eswar Prasad and others), Chang-Tai Hsieh, one of the authors of Chen et al.'s article, noted the smoothing problem and explained that they did not trust the official deflators but hoped that someone else would investigate whether the official deflator numbers were right.

the former focusing on production, income and final use accounts for designated years and the latter focusing on annual GDP accounts and other statistics based on regular reports and surveys.

The SNA-type CIOTs are available in full accounts at current prices for every five years beginning in 1987, with the 2017 CIOT as the most recent one, and in reduced form between any two consecutive full accounts. The NBS also provides corresponding supply and use tables (CSUTs) together with the full CIOTs since 1987.[5] It should be noted that in this study we have disqualified the CIOTs in reduced forms for seemingly illogical structural changes in those tables. In addition to SNA-type CIOTs, there is also a set of MPS-type of input-output tables for 1981 that were converted to the SNA standards in Wu and Ito (2015) and used in this study. We obtain annual GDP statistics in nominal values and real growth rates from "National Accounts" and information on prices from "Prices" and "Employment and Wages" chapters of CSY (for examples, please refer to NBS, 2019). The data conditions allow us to work on a system of 37 industries that largely satisfies the ISIC two-digit industries and is in line with the China Industry Productivity (CIP) database project (Wu and Ito, 2015; Wu, 2016).

Considering the nature of national accounts and Chinese data problems, we rely on China's supply and use tables because they can in theory provide an integrated framework for checking consistency and completeness of national accounts data. For this purpose, we also need to adopt a supply-use table RAS of the WIOD (world input-output database) or the SUTRAS approach following Temurshoev and Timmer (2011) as a balancing framework to reconcile official GDP estimates obtained by different approaches.

To prepare for the SUTRAS procedures, we perform two tasks first, with one that integrates available national accounts data using the CSY annual GDP values as "control totals" and the CIOT benchmark input-output accounts as "control structures" and the other one that reconstructs the benchmark CSUTs with the benchmark CIOTs to adjust for the incompleteness of the official CSUTs. These two tasks are followed by a SUTRAS-construction of CSUTs in time series and then a transformation from the so-constructed CSUT series to a new CIOT series, following the standard practice recommended by European Communities (2008).

[5] References for CIOTs are listed as follows: EFCSPC and DNEB (1986) for the 1981 CIOT; DNEB and ONIOS (1991) for the 1987 CIOT; DNEA (1996, 1999, 2006, 2009, 2015, 2019) for the 1992, 1997, 2002, 2007, 2012, and 2017 CIOT, respectively.

The last step of this data construction work is to build up a matrix of producer price indices (PPIs) from various official sources (such as the price data from chapter "Prices", nominal wage index from chapter "Employment and Wages" of CSY), as a proxy for changes in the basic prices at industry level in the CIOT system. Through the reconstructed CIOTs, the PPIs are used to systematically generate a set of price indices for purchasers or users, termed as user price indices or UPIs in this study. Based on PPIs and UPIs, we can also derive a set of price indices for value added by industry, or VPIs. These price indices help us assess the implicit value-added price indices in the CSY-reported GDP accounts, denoted as VPI* in this study.

Reconstruction of value added and gross output

There is no explanation in the official statistical system about the practical coherence of the CIOTs and the CSY-reported GDP accounts although they are conceptually consistent and reconcilable. It is important for us to make the two types of accounts consistent. As introduced briefly earlier, our strategy is to use the CSY-reported GDP values in nominal terms as the "control totals" and the benchmark CIOT value-added structure across sectors and industries as "control structures" to reconstruct the entire system with their own coherence. Specifically, through an interpolation of the CIOT "control structures", we can breakdown the broadly classified GDP accounts, usually in nine broad sectors, into the CIOT industries in time series, usually in over 100 industries, and then relying on the CIOT framework, we can further use the CIOT value-added to gross output ratio to derive industry-level gross output, hence generating industry-level intermediate inputs. Let us explain it in a more generalized manner.

We start with Equation (1) to reconstruct the value added of the Chinese system of national accounts (CSNA) in time series, denoting P as price, Q as quantity, and V as value added, hence PQ standing for any factor in nominal terms, and explain how the value added at industry-level of a sector is constructed with the given CIOT and CSY-reported GDP:

$$(1) \qquad (PQ)_{i\in I,t}^{V(CSNA)} = (PQ)_{I,t}^{V(CSY)} \times \left[\frac{(PQ)_{i\in I,t\in\tau(a,b)}^{V(CIOT)}}{\sum_{i\in I}(PQ)_{i\in I,t\in\tau(a,b)}^{V(CIOT)}}\right]$$

where i denotes an industry (i = *1, 2, ..., n*) or sub-sector of a broad sector *I* (*I = 1, 2, ..., m*) that matches the classification of the GDP accounts, *t* stands for time and τ (a, b) for any two consecutive benchmarks, *a*, *b*. The reconstructed industry or subsector-level results are fully additive, which are not only consistent with the aggregate GDP, but satisfying the given IOT structures that are interpolated between τ (a) and τ (b). In reconstructing Chinese national accounts, to make the best use of the available data and establish a long enough time series, we first follow the CIP classification system that classifies CIOTs into 37 industries, and then group them into 9 broad sectors, hence connecting CIOT structures with the classification of the CSY-reported GDP accounts.

Next, with Y denoted as gross output in Equation (2), we construct gross output series as follows:

$$(PQ)_{i\in I,t}^{Y(CSNA)} = \left[\frac{(PQ)_{I,t}^{V(CSY)}}{\varphi_{I,t}}\right] \times \left[\frac{(PQ)_{i\in I,t\in\tau(a,b)}^{Y(CIOT)}}{\sum_{i\in I}(PQ)_{i\in I,t\in\tau(a,b)}^{Y(CIOT)}}\right] \quad (2)$$

On the right side of Equation (2), the denominator of the first factor $\varphi_{I,t} = \frac{(PQ)_{I,t\in\tau(a,b)}^{V(CIOT)}}{(PQ)_{I,t\in\tau(a,b)}^{Y(CIOT)}}$ is the ratio of value added to gross output in time series for sector I, obtained by interpolating this ratio between consecutive CIOT benchmark years. Thus, the first factor gives the gross output value in time series for sector I, whereas the second factor provides the gross output structure of industries within sector I, also constructed by interpolating the industry structure between consecutive CIOT benchmark years. The gross output value of the Chinese national accounts is hence reconstructed by multiplying these two factors.

Reconstruction of benchmark CSUTs

In the absence of standard SUTs, we rely on the rough industry-by-commodity supply tables published with China's full input-output accounts every five year since 1987 and benchmark CIOTs to construct full benchmark SUTs. Let us start with the following supply-table structure that express how commodity c is supplied by industry i, that is, the transaction part in a supply table. $(PQ)_c^{Y(SUP)}$ denotes the total supply of commodity c and $(PQ)_i^{Y(SUP)}$ represents the total output of industry i.

The structure of supply table in the reduced version

	Industry i	Total supply
Commodity c	$(PQ)_{c,i}^{T(SUP)}$	$(PQ)_c^{Y(SUP)}$
Total output	$(PQ)_i^{Y(SUP)}$	

where c denotes commodities, T represents transaction. The transaction part of a supply table provides a detailed picture of the supply of goods and services by the production of domestic industries and imports.

Given that the Chinese official statistics only report the broad industry-by-commodity supply tables, our strategy is to use the detailed benchmark CIOTs to reconstruct benchmark Chinese supply tables, or CSUPs, to satisfy the requirement of the SUTRAS program that is used later. The benchmark CSUPs are reconstructed through the following steps of transformation as:

(3) $$(PQ)_{c,i,\tau}^{T(CSUP)} = (PQ)_{c,i,\tau}^{T(CSUP^{*})}$$

where CSUP* denotes adjusted Chinese official supply-tables by the RAS program. As explained in Equation (3), we first use the commodity shares of a given benchmark CIOT to split industries and commodities in a corresponding official CSUP to obtain initial values, and then with the initial values, together with "control totals" taken the reorganized benchmark CIOT, we conduct a RAS procedure to obtain the industries and commodities for the industrial sector as required by the supply table in the SUTRAS program.

(4) $$(PQ)_{c,i,\tau}^{T(CSUP)} = (PQ)_{c,i,\tau}^{Y(CIOT)}$$

We use Equation (4) to construct the part of non-industrial sectors in a supply table, which assumes that each non-industrial sector only produces products/services which belong to its own sector.

(5) $$(PQ)_{c,\tau}^{Y(CSUP)} = \sum_{i}(PQ)_{c,i,\tau}^{T(CSUP)}$$

(6) $$(PQ)_{i,\tau}^{Y(CSUP)} = \sum_{c}(PQ)_{c,i,\tau}^{T(CSUP)}$$

Equations (5) and (6) are accounting identities, that is, the total supply of commodity c is the sum of domestic production (implicitly including import), and the total output of industry i is equal to the sum of all commodities produced within this industry, respectively.

Next, given that the official statistics do not provide standard use tables, our strategy is to rely on the benchmark CIOTs to construct benchmark Chinese use tables, or CUSEs, because the CIOTs contain the information of the use of goods and services in the production process of an industry. Based on the structure of a standard use table, as presented below, we show how benchmark CUSEs are constructed by using the data from the benchmark CIOTs.

The structure of use table in the reduced version

	Industry i	Final use	Total use
Commodity c	$(PQ)_{c,i}^{T(USE)}$	$(PQ)_{c}^{F(USE)}$	$(PQ)_{c}^{Y(USE)}$
Value added	$(PQ)_{i}^{V(USE)}$		
Total output	$(PQ)_{i}^{Y(USE)}$		

where F denotes final use, including consumption, gross capital formation, and exports. The transaction part of a use table provides the information of the use of goods and services for intermediate consumption. The use table also shows how the value added is generated by industries in the domestic economy.

The benchmark CUSEs are constructed as:

(7) $$(PQ)_{c,i,\tau}^{T(CUSE)} = (PQ)_{c,i,\tau}^{T(CIOT)}$$

Equation (7) shows that by assuming the use of goods and services of intermediate consumption of an industry in a use table is the same as it in an input-output table, the transaction part of the benchmark CUSEs is transformed from the benchmark CIOTs, which are reorganized to meet the classification of industries and commodities in a use table in the SUTRAS program.

(8) $$(PQ)_{c,\tau}^{F(CUSE)} = (PQ)_{c,\tau}^{F(CIOT)}$$

Equation (8) shows that the final uses of commodity c are also transformed from the reorganized CIOTs.

(9) $$(PQ)_{i,\tau}^{V(CUSE)} = (PQ)_{i,\tau}^{V(CIOT)}$$

Equation (9) states that the value added generated by industry i is the same as it in the reorganized CIOTs.

(10) $$(PQ)_{c,\tau}^{Y(CUSE)} = \sum_i (PQ)_{c,i,\tau}^{T(CUSE)} + (PQ)_{c,\tau}^{F(CUSE)}$$

$$(11) \qquad (PQ)_{i,\tau}^{Y(CUSE)} = \sum_c (PQ)_{c,i,\tau}^{T(CUSE)} + (PQ)_{i,\tau}^{V(CUSE)}$$

Equations (10) and (11) are the accounting identities for a use table, which show that the total output of commodity c is equal to the sum of amounts of intermediate uses consumed by all industries and final use, and the total output of industry i is equal to the sum of all commodities consumed in production process and value added, respectively.

Equations (12) and (13) are balance conditions in the construction of benchmark Chinese SUTs, which show that the total supply of commodity c is equal to its total use, and the total output of industry i is equal to its total use, respectively.

$$(12) \qquad (PQ)_{c,\tau}^{Y(SUP)} = (PQ)_{c,\tau}^{Y(USE)}$$

$$(13) \qquad (PQ)_{i,\tau}^{Y(SUP)} = (PQ)_{i,\tau}^{Y(USE)}.$$

Construction of CSUTs in time series

To construct CSUTs in time series using the SUTRAS approach, developed by Temurshoev and Timmer (2011), in addition to the so-constructed benchmark CSUTs and the industry-level value added and gross output in time series that are already built up with the benchmark CIOTs and CSY-based annual GDP accounts, we have also accomplished two indicators in time series, that is, exports and imports by commodity, constructed with the UN commodity database and CIOTs, and inventory changes by commodity, linearly interpolated for non-benchmark years.

Following Temurshoev and Timmer (2011), the supply and use tables at purchasers' price can be jointly estimated as:

$$(14) \qquad \mathbf{U} = \widehat{\mathbf{r}_u}\mathbf{G}_{\boldsymbol{\tau}}\widehat{\boldsymbol{\beta}_u} - \widehat{\mathbf{r}_u}^{-1}\mathbf{N}_{\boldsymbol{\tau}}\widehat{\boldsymbol{\beta}_u}^{-1} \text{ and } \mathbf{S} = \widehat{\mathbf{r}_s}\mathbf{G}_{\boldsymbol{\tau}}^{\mathbf{s}}\widehat{\mathbf{r}_u}^{-1} - \widehat{\mathbf{r}_s}^{-1}\mathbf{N}_{\boldsymbol{\tau}}^{\mathbf{s}}\widehat{\mathbf{r}_u}.$$

where bold letters represent a matrix. $\mathbf{S}$ and $\mathbf{U}$ are the estimated supply and use tables, respectively. $\mathbf{G}_{\boldsymbol{\tau}}$ is a matrix with all non-negative entries of $\mathbf{U}_{\boldsymbol{\tau}}$ (i.e., the use table at benchmark year), and $\mathbf{N}_{\boldsymbol{\tau}} = \mathbf{G}_{\boldsymbol{\tau}} - \mathbf{U}_{\boldsymbol{\tau}}$ contains absolute values of the negative elements of $\mathbf{U}_{\boldsymbol{\tau}}$. Similarly, $\mathbf{G}_{\boldsymbol{\tau}}^{\mathbf{s}}$ is a matrix with all non-negative entries of $\mathbf{S}_{\boldsymbol{\tau}}$ (i.e., the supply table at benchmark year), and $\mathbf{N}_{\boldsymbol{\tau}}^{\mathbf{s}} = \mathbf{G}_{\boldsymbol{\tau}}^{\mathbf{s}} - \mathbf{S}_{\boldsymbol{\tau}}$. $\hat{\mathbf{x}}$ denotes the $n \times n$ diagonal matrix with the elements of $\mathbf{x}$ on its main diagonal and zeros elsewhere.

Equation (14) shows that in order to jointly estimate consistent SUTs one needs to compute only three dependent multipliers $\mathbf{r}_u$, $\boldsymbol{\beta}_u$, and $\mathbf{r}_s$. Their dependency reflects the fact that all the components of SUTs are estimated simultaneously (for details see Temurshoev and Timmer, 2011).

Transformation of CSUTs to CIOTs

Our final step is to transform time series of SUTs into CIOTs, which follows the transformation methodology recommended by Chapter 11 of European Communities (2008). SUTs can be transformed to input-output tables in many ways. It is more common to transform SUTs into symmetric input-output tables. In this study, we adopt Model D in European Communities (2008, pp. 347-351), i.e., transforming SUTs into industry-by-industry CIOTs. Model D assumes that the product sales structure is fixed, that is, each product has its own specific sales structure, irrespective of the industry where it is produced. The SUTs-IOTs transformation formulas in Model D are presented as follows.

Transformation matrix $\boldsymbol{TM}_{i\times c} = \left[(\boldsymbol{PQ})^{\boldsymbol{T}(\boldsymbol{CSUP})}{}_{\boldsymbol{c}\times\boldsymbol{i}}\right]' \times \left\{\boldsymbol{diag}[(\boldsymbol{PQ})^{\boldsymbol{Y}(\boldsymbol{CSUP})}{}_{\boldsymbol{c}\times\boldsymbol{1}}]\right\}^{-1}$

Intermediate uses $(\boldsymbol{PQ})^{\boldsymbol{T}(\boldsymbol{CIOT})}{}_{\boldsymbol{i}\times\boldsymbol{i}} = \boldsymbol{TM}_{\boldsymbol{i}\times\boldsymbol{c}} \times (\boldsymbol{PQ})^{\boldsymbol{T}(\boldsymbol{CUSE})}{}_{\boldsymbol{c}\times\boldsymbol{i}}$

Final uses $(\boldsymbol{PQ})^{\boldsymbol{F}(\boldsymbol{CIOT})}{}_{\boldsymbol{i}\times\boldsymbol{m}} = \boldsymbol{TM}_{\boldsymbol{i}\times\boldsymbol{c}} \times (\boldsymbol{PQ})^{\boldsymbol{F}(\boldsymbol{CUSE})}{}_{\boldsymbol{c}\times\boldsymbol{m}}$

Value added $(\boldsymbol{PQ})^{\boldsymbol{V}(\boldsymbol{CIOT})}{}_{\boldsymbol{1}\times\boldsymbol{i}} = (\boldsymbol{PQ})^{\boldsymbol{V}(\boldsymbol{CUSE})}{}_{\boldsymbol{1}\times\boldsymbol{i}}$

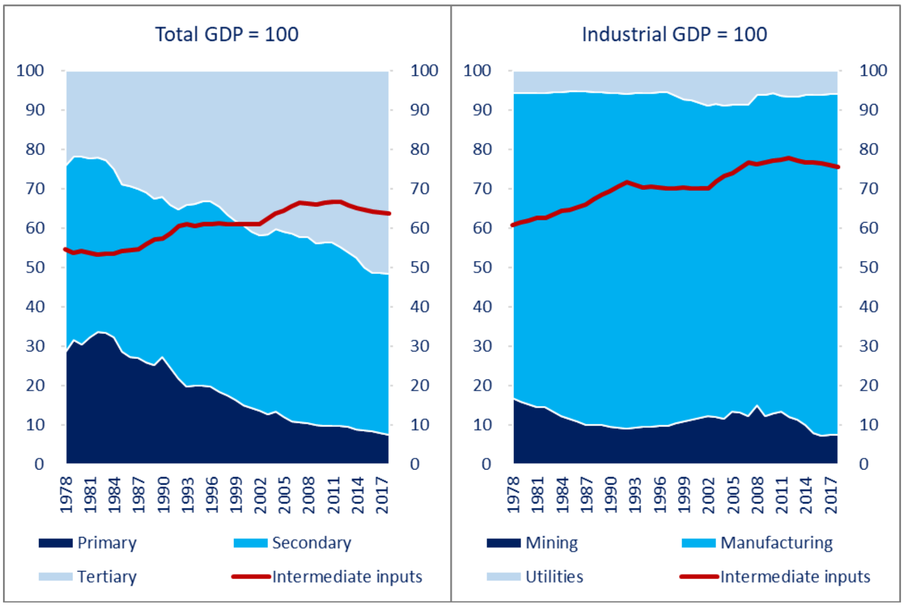
Gross output $(\boldsymbol{PQ})^{\boldsymbol{Y}(\boldsymbol{CIOT})}{}_{\boldsymbol{1}\times\boldsymbol{i}} = (\boldsymbol{PQ})^{\boldsymbol{Y}(\boldsymbol{CUSE})}{}_{\boldsymbol{1}\times\boldsymbol{i}}$

where a matrix with a prime denotes its transposition. m is the types of final uses. $\boldsymbol{TM}$ stands for the transformation matrix, which represents the share of commodity c supplied by industry i in the total amount of commodity c. The subscripts denote the dimension of each matrix.

A glance at the reconstructed national accounts

To have a quick glance at the results of the reconstructed Chinese national and industrial economies, we show its structural changes in Figure 1. It is sensible in economics to examine structural changes in nominal terms rather than in constant terms because the latter not only inevitably introduces biases of fixed weights but unrealistically assumes that prices play little role in the reallocation of resources. In other words, a view in nominal terms in this regard is one that considers the relative costs of factors, as well as intermediate inputs, which essentially drive the structural changes of an economy.

FIGURE 1
STRUCTURAL CHANGES OF CHINA'S NATIONAL AND INDUSTRIAL ECONOMIES, AND THE ROLE OF INTERMEDIATE INPUTS
(GDP = Gross output value – Intermediate inputs, in current yuan)



Source: Authors' estimates.

In the first panel, Figure 1 shows that the share of the primary sector (agriculture only, not included mining) in the aggregate GDP underwent a constant decline and that of the tertiary sector continuously rose, whereas that of the secondary sector (industrial and construction) remained almost unchanged. This suggests that the transformation of the post-reform Chinese economy has been mainly from the primary sector to the tertiary sector rather than taking the secondary sector as an important step stone. In fact, as shown in the second panel of Figure 1, the structure of the industrial economy also remained largely stable, with a slow, yet not steady, decline in mining, while a slow rise in manufacturing, leaving the share of utilities unchanged.

Meanwhile, the economy experienced a significant rise in the share of intermediate inputs, marked by the line dividing the gross output value of the economy (completely overlapping the GDP in the chart), which indicates the increasing role of intermediate costs in producing value added. The expansion of the production division in general tends to enlarge the share of intermediate inputs along with economic development. Nevertheless, this may not be all a good sign if the economy's productivity performance is deteriorating rather than improving (Wu, 2019). What more important to the present study, as we show in the next step of our data construction, is that a systematic measure of intermediate inputs in coherence with complete national accounts can facilitate us to gauge the role of changes in input prices relative to that in output prices.

Construction of industry-level PPIs

There are no ready-for-use producer price indices in Chinese official statistics that match the national accounts. There are PPIs for the industries of the industrial sector at 2-digit level, yet only those above the official threshold of annual sales. There are not PPIs for non-industrial sectors, especially service industries. We explain our approach to constructing PPI for each of the CIP 37 industries in Table 1 and the data sources.

TABLE 1
SOURCES OF INDUSTRY-SPECIFIC PPIS AND HANDLING METHODS

Industry (CIP Code)	Approach	Source
Agriculture (1)	Aggregate PPI for all agricultural products	"Prices", CSY
Mining (2-5)	Industry-specific PPIs, unadjusted	"Prices", CSY
Manufacturing (6-24)	Industry-specific PPIs, geometric average of sub-industries	"Prices", CSY
Utilities (25)	Industry-specific PPIs, geometric average of sub-industries	"Prices", CSY
Construction (26)	Investment price index of construction and installation	"Prices", CSY
Wholesale and retail (27)	Implicit value-added deflator	"National Accounts", CSY
Hotels and catering (28)	National CPI before 1994; price index of "dining out" (a component of CPI) for 1994 onwards	"Prices", CSY
Transportation and storage (29)	Transportation component of CPI, excluding the price of equipment (vehicles) for 2001 onwards	"Prices", CSY
Post and telecommunication (30)	Telecommunication component of CPI	"Prices", CSY
Financial services (31)	Geometric average of transportation and storage (29), post and telecommunication (30), real estate (32), and other services (37)	
Real estate services (32)	Estimated based on implicit service charge per square meter for 1993 onwards and assumed to move along with housing component of CPI	"Prices", "Real Estate", CSY
Leasing, business services (33)	As financial services (31)	
Public management (34)	National CPI before 2002; adjusted to nominal wage index of urban staff from 2002 onwards	"Prices", "Employment and Wages", CSY
Education (35)	Education component of CPI before 2002; adjusted to nominal wage index of urban staff from 2002 onwards	"Prices", "Employment and Wages", CSY
Healthcare, social welfare (36)	Medical care service component of CPI before 2002; adjusted to nominal wage index of urban staff from 2002 onwards	"Prices", "Employment and Wages", CSY
Other services (37)	Average of culture, sports, entertainment, personal repair components of CPI	"Prices", CSY

Source: CSY (various issues), see "approach" for a brief explanation for any adjustments.

Assessing the constructed PPIs with further adjustment

As indicated in Table 1, we have constructed a matrix of PPIs for 37 industries as classified in the CIP data project. In Table 2, we report the constructed PPIs in nine broad sectors based on the economy-wide 37 industries for an important comparison with official price indices because the CSY-reported nominal GDP and its real growth rates are only classified in nine sectors. To conduct a sensible comparison, we derive the implicit value-added price index for each of the nine sectors based the official GDP statistics, denoted as VPI*. Conceptually, in the case of using single deflation method, value-added prices are equal to both output or producer prices, denoted as PPI, and input or purchaser (user) prices, denoted as UPI, that is, PPI = UPI = VPI for any industry. In the case of using double deflation method, the UPI of an industry is however estimated by the input cost-weighted PPIs across all industries, based on which the industry's VPI can be derived. Therefore, PPI ≠ UPI ≠ VPI in double deflation.

Since the official growth rates are based on or close to the single deflation method as widely believed, we assume that in official GDP statistics, VPI* = PPI* = UPI*. Thus, in Table 2, we only compare VPI* with our constructed PPI at the sector level. In addition, we also depict the full series of these indices in Figure 2 to intuitively help this comparison. The indices are based on 1992 aiming to better reflect the trend of price changes since Deng's call for "bolder reforms" that led to China's adoption of a model of "socialist market economy" in 1993. This comparison is motivated by an established and influential hypothesis that official price statistics are downward biased to exaggerate China's real growth, confirmed by various empirical investigations (Field 1992; Rawski, 1993; Ren, 1997; Maddison, 1998; Wu, 2000) but never tested though a complete system of national accounts like the one pursued in this study. Judged by this hypothesis, we hence assume that a higher value-added price level out of the comparison, either the official GDP accounts based VPI* or our constructed PPI for a given industry, is closer to the reality and use it to conduct a further adjustment to the PPI.

Based on the average price change over the entire period 1978-2018 in Table 2, there are six sectors whose PPI shows a faster price change than that of the respective VPI*, namely, the industrial sector, the transport, storage and telecommunication sector, the hotel and catering sector, the financial service sector, the real estate sector, and the other services sector, consisting of business services, non-market services (education, healthcare and government) and personal services, which confirms the hypothesis of downward bias in official prices. The PPIs of these sectors are maintained intact in our further adjustment. Nonetheless, there are two sectors, agriculture and construction, whose constructed PPI show a slower price change than that of the official VPI*. Based on this comparison, we further adjust our matrix of PPIs for the constructed national accounts and reported the results in Table 3. It should be mentioned that in the case of double deflation, even there is only one industry whose producer price changes, all other industries in the system that use the output of this industry as one of their inputs will also incur price changes in UPI and VPI.

There are no data on individual industries of the industrial sector in the CSY-reported GDP accounts, we feel justified to maintain official PPIs for these industries reported in the regular CSY reports of "Price Statistics". These PPIs are compiled only for those enterprises above the NBS threshold that changed several times in history ranging from ownership, administrative level, to the value of annual sales. We use these PPIs by assuming that in any industry all enterprises face the same prices no matter whether they satisfy the threshold.

In Table 4, we reorganize the official price data for 39 industries into seven groups and compare their PPIs with the official VPI* for the whole industrial sector. In essence, the official industrial VPI* is the mean of price changes across all industries and the PPIs of individual industries are deviations from the mean, assuming that we are in the case of single deflation. In general, for the entire period or over subperiods, the mining and the energy sector, sometimes also involving the heavy material sector, experienced much higher price changes compared to the industrial mean, whereas the ICT producing sector underwent distinct price declines. Such differences undoubtedly affected input prices of other industries that used the products of these industries as their inputs, which support the use of the double deflation method.

In the case of double deflation, we estimate our VPIs for each sector, also shown in Table 4. These VPIs are not directly comparable with official industrial VPI* because the latter does not follow the concept of double deflation. As explained in Section 4, our VPIs are more meaningful especially when the changes of a sector's purchaser/user price, UPI, are significantly different from those of its producer price, PPI, as we just observed and discussed.

TABLE 2
CHANGES IN CONSTRUCTED PPI, UPI AND VPI IN COMPARISON WITH OFFICIAL VPI* BY SECTOR
(Percent per annum)

	1978-2018				1978-1984				1984-1991				1991-1996			
	PPI	UPI	VPI	VPI*	PPI	UPI	VPI	VPI*	PPI	UPI	VPI	VPI*	PPI	UPI	VPI	VPI*
Total	5.2	4.6	5.2	5.0	0.5	2.2	0.9	2.6	10.1	10.0	9.1	7.6	14.4	13.3	12.9	12.8
Agricultural	5.9	4.8	5.7	6.5	6.2	2.6	7.3	6.8	8.6	9.5	7.2	8.9	16.2	13.8	14.7	16.2
Industrial	3.7	4.5	0.9	3.1	-0.5	2.7	-3.7	0.8	8.9	9.7	6.4	4.8	13.0	13.1	8.5	10.5
Construction	5.2	4.7	5.6	6.0	1.4	3.1	-3.6	4.2	9.9	10.5	6.2	8.4	12.6	12.5	9.5	17.3
Wholesale, Retails	6.2	5.0	4.3	6.2	-2.7	-0.4	-14.8	-2.7	19.5	10.2	20.6	19.5	15.2	14.3	13.7	15.2
Transport, Telecom.	5.9	5.6	5.5	5.1	0.2	3.4	0.1	2.4	15.6	11.3	13.2	11.6	11.7	14.7	13.3	10.1
Hotel, Catering	5.8	4.5	6.9	4.9	1.5	-1.1	7.3	-0.3	9.5	10.0	5.7	12.7	17.0	14.2	17.1	8.1
Financial Services	6.9	6.0	6.9	6.0	1.5	2.7	0.9	2.5	12.0	10.5	12.0	8.6	18.3	14.8	18.3	15.3
Real Estate	8.7	5.3	9.4	7.1	4.7	0.0	10.1	4.2	9.7	10.1	8.6	5.9	18.7	14.2	17.8	13.4
Other Services	11.0	4.7	14.9	6.7	3.9	0.0	8.2	3.2	13.2	10.8	13.6	7.7	20.8	13.8	23.4	15.4

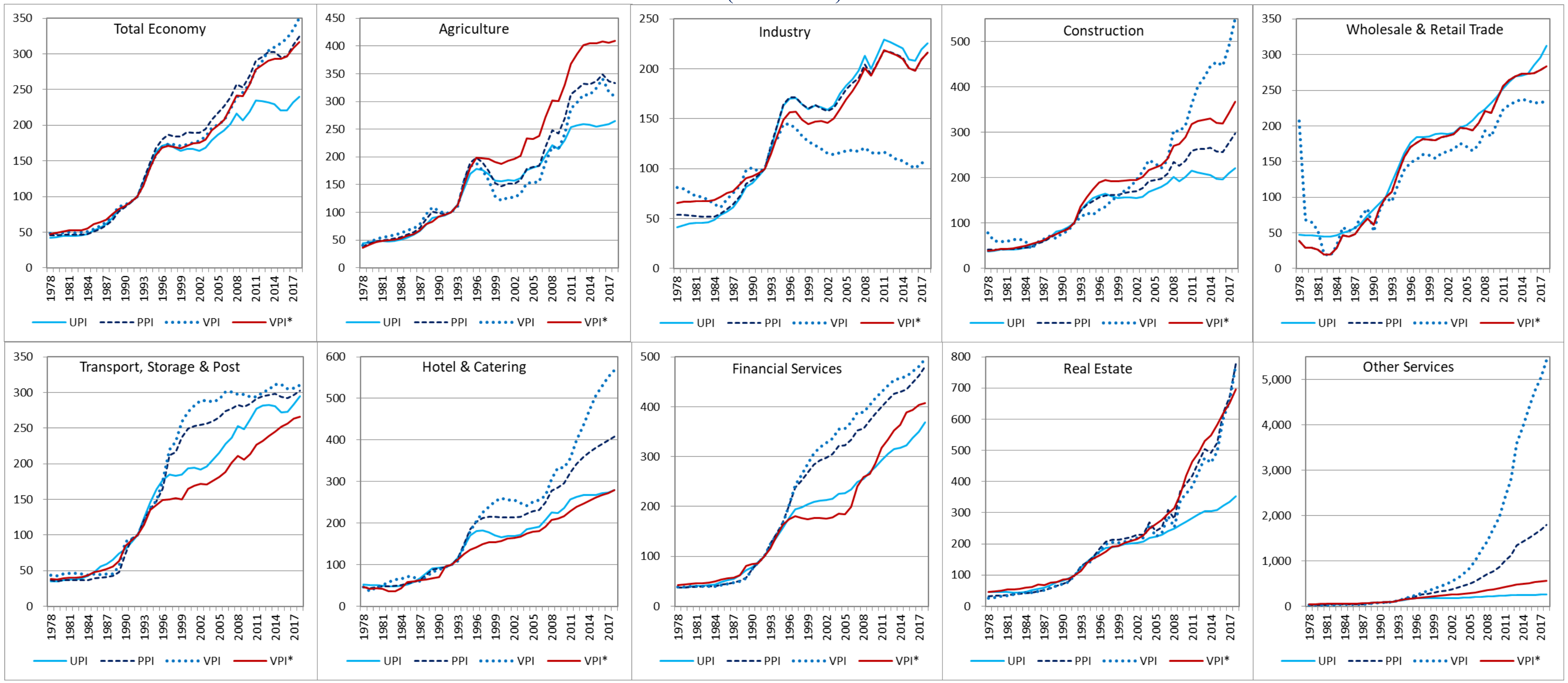
	1996-2001				2001-2007				2007-2012				2012-2018			
	PPI	UPI	VPI	VPI*	PPI	UPI	VPI	VPI*	PPI	UPI	VPI	VPI*	PPI	UPI	VPI	VPI*
Total	1.1	-0.6	0.8	0.7	4.0	3.3	4.1	4.3	4.4	3.1	5.4	5.0	1.6	0.5	3.2	1.8
Agricultural	-5.0	-2.3	-7.3	-0.6	6.4	4.2	7.3	6.0	8.4	5.1	9.7	7.4	0.6	0.5	0.7	1.0
Industrial	-1.3	-1.0	-3.7	-1.1	3.0	3.5	-0.3	4.1	2.7	2.9	-0.6	3.0	0.0	0.0	-0.6	0.1
Construction	1.5	-0.5	6.9	0.6	3.6	3.1	5.0	3.7	5.0	2.5	11.5	6.2	2.1	0.9	5.5	2.1
Wholesale, Retails	1.6	1.5	1.7	1.6	1.8	2.3	1.3	1.8	5.3	3.8	5.9	5.3	1.2	3.0	0.3	1.2
Transport, Telecom.	9.4	1.9	10.2	2.6	1.5	3.4	1.1	3.0	1.2	3.6	-0.1	2.9	0.5	0.8	0.6	2.3
Hotel, Catering	1.1	-1.4	4.6	2.9	2.6	3.6	0.8	2.8	6.6	4.9	8.6	4.6	3.0	1.0	6.0	2.6
Financial Services	7.8	3.8	9.7	0.3	3.2	2.7	3.4	5.5	3.2	4.2	2.6	6.8	2.5	3.3	1.9	3.4
Real Estate	3.8	3.0	3.8	5.0	6.3	3.0	6.1	6.1	9.1	4.1	9.2	10.7	9.3	3.0	10.6	5.9
Other Services	9.2	0.9	14.0	6.6	10.3	2.3	17.1	4.9	12.4	3.2	18.1	6.2	8.2	1.5	11.8	3.8

Sources: Authors' estimated PPIs, UPIs and VPIs. Official VPI*s are calculated as implicit deflators based on data from CSY-reported GDP accounts (NBS, 2019). Also see Table 1 for the sources of the basic data and data handling approaches.

Notes: In the case of using the single deflation method, conceptually PPI=UPI=VPI. In the case of using the double deflation method, UPI by industry is estimated by input cost-weighted PPIs across all industries in our constructed 37-industry system, based on which our VPI by industry can be derived.

FIGURE 2

GAUGING PRICE CHANGES IN THE CHINESE ECONOMY:
CONSTRUCTED PPI AND DERIVED UPI AND VPI IN COMPARISON WITH OFFICIAL IMPLICIT GDP DEFLATOR OR VPI* BY SECTOR
(1992 = 100)



Sources: Authors' estimated PPIs, UPIs and VPIs. Official VPI*s are calculated as implicit deflators based on data from CSY-reported GDP accounts (NBS, 2019). Also see Table 1 for the sources of the basic data and data handling approaches.

Notes: See Table 2.

Table 3
Changes in Further Adjusted PPI', UPI' and VPI' in Comparison with Official VPI* by Sector
(Percent per annum)

	1978-2018				1978-1984				1984-1991				1991-1996			
	PPI'	UPI'	VPI'	VPI*	PPI'	UPI'	VPI'	VPI*	PPI'	UPI'	VPI'	VPI*	PPI'	UPI'	VPI'	VPI*
Total	5.2	4.7	5.5	5.0	0.6	2.3	1.5	2.6	10.1	10.0	9.0	7.6	14.6	13.4	13.7	12.8
Agricultural	6.5	5.1	6.6	6.5	6.8	2.8	7.9	6.8	8.9	9.7	7.8	8.9	16.2	14.0	15.2	16.2
Industrial	3.7	4.6	0.7	3.1	-0.5	2.8	-3.8	0.8	8.9	9.8	6.2	4.8	13.0	13.2	8.4	10.5
Construction	6.0	4.7	8.2	6.0	4.2	3.2	6.8	4.2	8.4	10.5	1.6	8.4	17.3	12.5	23.1	17.3
Wholesale, Retails	6.2	5.0	4.3	6.2	-2.7	-0.4	-14.9	-2.7	19.5	10.2	20.6	19.5	15.2	14.3	13.7	15.2
Transport, Telecom.	5.9	5.6	5.5	5.1	0.2	3.4	0.1	2.4	15.6	11.3	13.2	11.6	11.7	14.7	13.3	10.1
Hotel, Catering	5.8	4.7	6.6	4.9	1.5	-1.1	7.2	-0.3	9.5	10.3	5.6	12.7	17.0	14.4	16.9	8.1
Financial Services	6.9	6.0	6.9	6.0	1.5	2.7	0.9	2.5	12.0	10.5	12.0	8.6	18.3	14.9	18.2	15.3
Real Estate	8.7	5.4	9.4	7.1	4.7	0.0	10.1	4.2	9.7	10.1	8.6	5.9	18.7	14.5	17.7	13.4
Other Services	11.0	4.7	14.9	6.7	3.9	0.0	8.2	3.2	13.2	10.8	13.6	7.7	20.8	13.9	23.3	15.4
	1996-2001				2001-2007				2007-2012				2012-2018			
	PPI'	UPI'	VPI'	VPI*	PPI'	UPI'	VPI'	VPI*	PPI'	UPI'	VPI'	VPI*	PPI'	UPI'	VPI'	VPI*
Total	1.2	-0.1	1.2	0.7	4.0	3.3	4.1	4.3	4.4	3.0	5.7	5.0	1.6	0.5	3.2	1.8
Agricultural	-0.6	-0.4	-0.7	-0.6	6.0	4.1	6.8	6.0	7.4	4.9	8.6	7.4	1.0	0.6	1.3	1.0
Industrial	-1.3	-0.5	-4.8	-1.1	3.0	3.5	-0.3	4.1	2.7	2.9	-0.5	3.0	0.0	0.0	-0.7	0.1
Construction	0.6	-0.3	2.9	0.6	3.7	3.1	5.1	3.7	6.2	2.5	16.4	6.2	2.1	0.9	5.5	2.1
Wholesale, Retails	1.6	1.6	1.6	1.6	1.8	2.4	1.3	1.8	5.3	3.8	5.9	5.3	1.2	3.0	0.3	1.2
Transport, Telecom.	9.4	1.9	10.2	2.6	1.5	3.4	1.1	3.0	1.2	3.6	-0.1	2.9	0.5	0.8	0.6	2.3
Hotel, Catering	1.1	0.0	2.7	2.9	2.6	3.6	0.9	2.8	6.6	4.8	8.8	4.6	3.0	1.1	5.9	2.6
Financial Services	7.8	3.7	9.7	0.3	3.2	2.7	3.4	5.5	3.2	4.2	2.6	6.8	2.5	3.3	1.9	3.4
Real Estate	3.8	2.9	3.8	5.0	6.3	3.0	6.2	6.1	9.1	4.2	9.2	10.7	9.3	3.0	10.6	5.9
Other Services	9.2	0.9	14.0	6.6	10.3	2.2	17.1	4.9	12.4	3.2	18.0	6.2	8.2	1.5	11.8	3.8

Sources: Authors' adjusted based on the constructed PPIs, UPIs and VPIs of Table 2. Official VPI*s are calculated as implicit deflators based on CSY-reported GDP accounts (NBS, 2019).

Notes: The adjustment of PPIs follows the hypothesis of downward bias in official prices (e.g., Field 1992; Rawski, 1993; Ren, 1997; Maddison, 1998). The constructed PPI by industry is adjusted upward by higher price changes as indicated by the movements of the constructed PPI and official VPI* that is equal to PPI* if following the official single deflation method. PPI', UPI' and VPI' are denoted for the adjusted PPI, UPI and VPI. See discussions in the text.

TABLE 4

CHANGES IN OFFICIAL INDUSTRIAL PPI, UPI AND VPI BY INDUSTRY IN COMPARISON WITH OFFICIAL INDUSTRIAL VPI*

(Percent per annum)

	1978-2018				1978-1984				1984-1991				1991-1996			
	PPI	UPI	VPI	VPI*	PPI	UPI	VPI	VPI*	PPI	UPI	VPI	VPI*	PPI	UPI	VPI	VPI*
Total industry	3.7	4.6	0.7	3.1	-0.5	2.8	-3.8	0.8	8.9	9.8	6.2	4.8	13.0	13.2	8.4	10.5
Mining	5.4	4.7	6.3	3.1	2.0	0.7	2.9	0.8	8.7	9.8	8.0	4.8	14.9	13.5	16.6	10.5
Energy	9.3	8.2	10.3	3.1	13.9	10.4	16.5	0.8	11.8	10.7	12.5	4.8	22.8	20.6	25.6	10.5
Heavy materials	4.6	5.3	2.6	3.1	4.3	3.8	5.2	0.8	10.1	10.6	8.9	4.8	12.6	13.9	9.3	10.5
Light materials	2.3	3.8	-2.4	3.1	-2.8	0.4	-10.3	0.8	7.7	9.1	4.2	4.8	9.2	11.8	0.9	10.5
Capital goods 1: Machinery	1.2	4.0	-5.1	3.1	-7.3	1.5	-22.8	0.8	7.3	10.0	1.4	4.8	9.0	12.0	0.9	10.5
Capital goods 2: ICT products	-5.2	-0.2	-17.7	3.1	-24.5	-9.4	-49.8	0.8	0.3	5.7	-12.0	4.8	3.5	8.5	-10.3	10.5
Consumer goods	3.5	5.0	0.1	3.1	-0.8	4.1	-10.9	0.8	9.0	9.6	7.2	4.8	12.3	13.3	9.4	10.5
	1996-2001				2001-2007				2007-2012				2012-2018			
	PPI	UPI	VPI	VPI*	PPI	UPI	VPI	VPI*	PPI	UPI	VPI	VPI*	PPI	UPI	VPI	VPI*
Total industry	-1.3	-0.5	-4.8	-1.1	3.0	3.5	-0.3	4.1	2.7	2.9	-0.5	3.0	0.0	0.0	-0.7	0.1
Mining	-2.4	0.8	-5.9	-1.1	9.3	4.0	15.3	4.1	6.5	3.6	10.3	3.0	-1.3	0.0	-2.9	0.1
Energy	6.7	5.5	8.5	-1.1	6.6	7.0	5.9	4.1	5.0	4.8	5.6	3.0	-1.2	-1.1	-1.2	0.1
Heavy materials	-2.7	-0.6	-8.5	-1.1	4.5	5.1	2.9	4.1	1.8	3.2	-3.6	3.0	0.4	0.1	0.9	0.1
Light materials	-2.5	-1.2	-6.1	-1.1	1.1	2.6	-3.8	4.1	2.3	3.3	-1.3	3.0	0.1	0.5	-1.3	0.1
Capital goods 1: Machinery	-2.0	-1.1	-4.4	-1.1	0.7	2.9	-6.8	4.1	0.7	1.5	-2.5	3.0	-0.1	0.1	-0.8	0.1
Capital goods 2: ICT products	-6.8	-3.7	-16.5	-1.1	-4.6	-1.4	-17.7	4.1	-2.1	-0.3	-11.0	3.0	-1.4	-0.7	-5.0	0.1
Consumer goods	-2.3	-0.8	-5.6	-1.1	2.0	3.1	-0.9	4.1	3.3	4.3	0.3	3.0	0.6	0.7	0.3	0.1

Sources: Authors' reconstructed industrial PPI by industry is based on official industrial price statistics. Official industrial VPI* is calculated as implicit deflator based on CSY-reported GDP accounts (NBS, 2019). Also see Table 1 for the sources of the basic data and data handling approaches.

Notes: See Table 2 for the estimation of UPI and VPI.

4. METHODOLOGY

If our reconstructed Chinese national accounts for 37 industries and their price indices are acceptable, to estimate the real growth rate of the Chinese economy, we need to deal with two methodological problems that have not been handled carefully, one is the deflation problem and the other is the aggregation problem.

The deflation problem

A concept of net output, or real value added, is desirable for a measure which excludes the contribution made to a given industry's output by inputs purchased from other industries (David, 1966). Given that net output is a theoretical concept in nature, the meaningful interpretation of real value added needs some assumptions. Assume that the production function is separable, or at least weakly separable, with primary inputs and intermediate input, and is also subject to primary inputs-generalized constant returns to scale and to technical change restricted to primary inputs, real value added refers to the contribution of primary inputs, economies of scale, and technical change in the production process (Hulten, 1973; Sato, 1976). David (1966) shows that under the assumptions that the production technology is constant returns to scale and perfect competition prevails in the product and purchased inputs markets, the direct deflation of an index of value added at current prices by the index of the price of an industry's product (e.g., PPI) will yield a correct measurement of real value added, which is the essence of single deflation.

The main shortcoming in single deflation is the assumption that price changes of output basically keep the same proportion as those of intermediate input. In practice, every industry usually consumes more than one type of intermediate inputs delivered from other industries (Hulten, 1978). It is difficult to keep the patterns of price changes of total intermediate input, a weighted average of price changes of various types of intermediate inputs used, the same as that of output. If the price change of output is faster than that of intermediate input, the application of single deflation will cause an upward-biased growth rate of real value added if the output price is used.

In order to better capture price changes of both output and various intermediate inputs, the double deflation method is theoretically sound to derive real value added (United Nations, 2009; OECD, 2001; European Communities, 2008). In this case, the real value added is obtained as the difference between real value of gross output which is derived by deflating the current value of gross output with appropriate output deflator, and real value of intermediate inputs which are derived by deflating the current value of intermediate inputs with appropriate intermediate deflators. The price changes of various intermediate inputs and gross output can be captured by producer price index of each industry.

The following is to show the difference in growth rate of real value added by using single and double deflation. Starting from the accounting identity, the nominal value added is the residual of gross output and total intermediate inputs, that is,

$$P_i^V Q_i^V = P_i^Y Q_i^Y - P_i^M Q_i^M \tag{15}$$

where Q_i^V, Q_i^Y, and Q_i^M are value added, gross output and intermediate input of industry i. P_i^V, P_i^Y and P_i^M are the corresponding prices. Time subscripts are suppressed for convenience wherever possible.

In case of single deflation, the real value added is estimated by deflating the current value of gross value added based on a price index, and the price index of gross value of output is usually adopted in single deflation. The real value added by single deflation can be expressed as:

$$V_i = \frac{P_i^Y Y_i - P_i^M M_i}{P_i^Y / P_i^{Y_0}} \tag{16}$$

where $P_i^{Y_0}$ represents the price of gross output at base year.

Taking the differential of Equation (16), we can derive the growth rate of real value added as:[6]

$$\Delta lnV_i^S = \frac{P_i^Y Y_i}{P_i^V V_i}\Delta lnY_i - \frac{P_i^M M_i}{P_i^V V_i}\Delta lnM_i - \frac{P_i^M M_i}{P_i^V V_i}(\Delta lnP_i^M - \Delta lnP_i^Y) \tag{17}$$

where ΔlnV_i^S is the growth rate of industry value added based on single deflation and P_i^V is equal to P_i^Y in case of single deflation.

[6] We calculate growth as log difference since economic data are not continuous over time but come in discrete-time units, i.e., $\Delta lnx_t = lnx_t - lnx_{t-1}$ represents the growth rate of x between time periods $t-1$ and t.

On the other hand, taking the differential of Equation (15), we can derive the growth rate of real value added by double deflation (ΔlnV_i^D) as:

(18) $$\Delta lnV_i^D = \frac{P_i^Y Y_i}{P_i^V V_i}\Delta lnY_i - \frac{P_i^M M_i}{P_i^V V_i}\Delta lnM_i$$

Combining Equations (17) and (18), we can derive the difference of the growth rate of industry value added between double deflation and single deflation, that is,

(19) $$\Delta lnV_i^D - \Delta lnV_i^S = \frac{P_i^M M_i}{P_i^V V_i}(\Delta lnP_i^M - \Delta lnP_i^Y)$$

which shows that the discrepancy of the growth rate of industry value added between double deflation and single deflation depends on the relative price changes of industry intermediate input and gross output. If the price change of intermediate input is increasing (decreasing) faster than that of gross output, the growth rate of industry value added will be underestimated (overestimated) by adopting single deflation.

The aggregation problem

Thus far, real value added and its growth rate have been discussed at industry level, and the question arises as to how to aggregate them with a view to obtain an overall measure of the growth rate of the whole economy. In aggregating, two choices can be made. The first one is to derive aggregate value added by summing up real value added of individual industries and then calculate its growth rate. The second one is aggregating the growth rates of value added of individual industries by following Tornqvist quantity index approach with the nominal shares of value added of each industry in the whole economy.

The first aggregation approach tends to cause the problem of substitution bias. The substitution bias is a possible problem with a price index. Consumers can substitute goods in response to price changes. A substitution bias exists if a price index does not take this change in purchasing choices into account, e.g., if the collection ("basket") of goods whose prices are compared over time is fixed. The Laspeyres and Paasche price indexes are commonly used to derive real value added. However, the Laspeyres price index uses quantities of a given base year as fixed weights and the Paasche price index uses quantities of a current year as fixed weights, both of which ignore substitution effects and cause the substitution bias. The former tends to give a higher rate of volume growth in years close to current year and the latter tends to give a lower rate of growth at the years closer to the current year (United Nations, 2003). The following first uses formulas to show the bias caused by using Laspeyres price index, and then move to the bias caused by using Paasche price index.

Following Huang et al. (2015), the difference between Laspeyres price index denoted at two base years, *0* and b (suppose the period b is prior to the period *0*), can be expressed as:

$$(20) \qquad P_L^0 - P_L^b = \frac{\sum_i P_i^{Y,t} Q_i^{Y,0}}{\sum_i P_i^{Y,0} Q_i^{Y,0}} - \frac{\sum_i P_i^{Y,t} Q_i^{Y,b}}{\sum_i P_i^{Y,0} Q_i^{Y,b}} = \sum_i \left\{ \left(\frac{P_i^{Y,t}}{P_i^{Y,0}} - P_L^0 \right) \left(\frac{Q_i^{Y,0}}{Q_i^{Y,b}} - Q_P^{0/b} \right) \frac{s_i^{0/b}}{Q_P^{0/b}} \right\}$$

where $s_i^{0/b} = \frac{P_i^{Y,0} Q_i^{Y,b}}{\sum_i P_i^{Y,0} Q_i^{Y,b}}$ is the hybrid expenditure shares corresponding to the quantity weights vector $Q^{Y,b}$ measured at the price vector of the price reference period $P^{Y,0}$. $Q_P^{0/b} = \frac{\sum_i P_i^{Y,0} Q_i^{Y,0}}{\sum_i P_i^{Y,0} Q_i^{Y,b}}$ is the Paasche quantity index between the weight reference period (*b*) and the price reference period (*0*).[7]

The first equation indicates that the Laspeyres price index (P_L^0) employs more up-to-date weights ($Q^{Y,0}$) than P_L^b. Because of price-induced commodity-substitution, we would expect a higher index series (P_L^b) in the general case. The second equation indicates that the covariance between the deviation of relative prices, $\left(\frac{P_i^{Y,t}}{P_i^{Y,0}} - P_L^0 \right)$, and the deviation of relative quantities, $\left(\frac{Q_i^{Y,0}}{Q_i^{Y,b}} - Q_P^{0/b} \right)$, are for different time periods. This implies that if price trends persist from period b to *0* and continue on from period *0* to t, and price-induced substitution behavior exists as expected, the P_L^b is likely to be higher than the P_L^0.

Similarly, we can decompose the difference between the Paasche price index denoted at two base years, t and b (suppose the period b is prior to the period t), as follows:

$$(21) \qquad P_P^t - P_P^b = \frac{\sum_i P_i^{Y,t} Q_i^{Y,t}}{\sum_i P_i^{Y,0} Q_i^{Y,t}} - \frac{\sum_i P_i^{Y,t} Q_i^{Y,b}}{\sum_i P_i^{Y,0} Q_i^{Y,b}} = \sum_i \left\{ \left(\frac{P_i^{Y,t}}{P_i^{Y,0}} - P_L^0 \right) \left(\frac{Q_i^{Y,t}}{Q_i^{Y,b}} - Q^{t/b} \right) \frac{s_i^{0/b}}{Q^{t/b}} \right\}$$

where $Q^{t/b} = \frac{\sum_i P_i^{Y,0} Q_i^{Y,t}}{\sum_i P_i^{Y,0} Q_i^{Y,t}}$ is the quantity index between the weight reference period (*b*) and the current period (*t*), measured at the prices of the price reference period (*0*).

[7] The detailed solution process is available from the authors upon on request.

From this decomposition, it can be seen that the Paasche price index (P_P^t) is likely to be less than P_P^b as long as the price trend between price reference period *0* and current period t is in the same direction as the price trend between basket reference period b and current period t.

In order to avoid the substitution bias in constant-price value aggregation, we use Tornqvist aggregation approach to derive the growth rate of the aggregate economy, i.e.,

(22) $$\Delta lnV = \sum_i \overline{w}_i \Delta lnV_i^D$$

where w_i is the nominal share of value added in gross output of industry i, "-" denotes two-period average.

5. Results and Implications

Using the national accounts and the price data reconstructed in Section 3 and following the methodologies of deflation and aggregation discussed in Section 4, we have now come out with various sets of results on the growth performance of the Chinese economy and its major sectors for the period 1978-2018. In what follows we present the results in a way that helps us identify the effects of adopting different price indices, deflation methods, and aggregation approaches on the measured growth performance for China and explore their implications.

Growth by alternative deflation approaches

China's different growth rates reported in Table 5 are obtained by applying different deflators, deflation approaches, and aggregation approaches to the same nominal national accounts we reconstructed following our data and methodological discussions in Section 3. Therefore, we implicitly assume that our methodology that integrates China's annual GDP accounts and benchmark input-output accounts into a complete system of national accounts through a supply-use framework is sound and acceptable.

In Table 5 we report our estimates in two panels with alternative aggregation approaches, specifically the upper one focusing on the usual constant-price value (CPV) aggregation approach and the lower one using the Törnqvist index aggregation approach. Each panel reports the results obtained by different deflation approaches using either official or our alternative deflators. Besides, on the top row of the table, we include the official reported or NBS growth rates as the reference to which our estimates obtained by alternative approaches are compared and discussed.

Let us start with the estimates in the first panel that adopts the CPV aggregation approach using alternative deflators and deflation methods. We can proceed with the following observations. First, not surprisingly we find clear substitution bias as expected, that is, the annual growth obtained by a deflator using an earlier base year, e.g., Laspeyres 1985, is faster than that using a later base year, e.g., Laspeyres 2015, no matter with which deflators, official or alternative. This is also confirmed by estimates obtained using Laspeyres deflators with other base years between 1985 and 2015, e.g., 1990, 1995, 2000, etc. This implies that any growth estimation without concerning the substitution bias can be distorted to the extent depending on the choice of the base year. Examining China's overall growth over the entire period or its subperiods, we nonetheless find that the Laspeyres 1985 growth estimates are the closest to the NBS estimates that have never been officially disclosed about how deflators are constructed. This finding confirms that the NBS estimates are upward-biased. We show that either the segmented Fisher index method or the full-series integrated Fisher index method can somewhat alleviate the bias while maintaining the official deflators and single deflation method. If convinced to accept our alternative deflators, as Table 5 shows, China's growth would be 8.5 per annum by the full-series Fisher method, that is, 1.0 percentage points (ppts) slower than the official 9.5, for the entire period in question.

Second, our estimates by double deflation approaches clearly suggest that the estimates by single deflation approaches, given the chosen deflator, contain an upward bias and the bias is larger by the full-series Fisher method than by the segmented Fisher method. If using the official deflators, the double-deflation estimated annual growth by the full-series Fisher method is 8.9 percent, compared to 9.2 if using the segmented Fisher method. However, if shifting to our deflators, the corresponding results would be 7.8 and 8.1 percent per annum.

Growth by alternative aggregation approaches

The growth rates presented in the first panel of Table 5 are first estimated at the broad sector level (nine sectors economy wide as categorized in the official statistics; refer to Table 6 below), and then aggregated to the national total by a constant price values (CPV) approach.[8] This will inevitably introduce some substitution bias caused by fixed base-year weights that cannot be

[8] The national total is derived by the CPV approach through 9 sectors in the all cases of single deflation, and through 37 sectors in the case of double deflation. The segmented Fisher, in either single deflation or double deflation, is obtained as the geometric average of the growth rate of the whole economy under two adjacent base years of Laspeyres price index. The full-series Fisher is obtained as the geometric average of the growth rate of the whole economy under all base years of Laspeyres price index.

completed removed by either of the Fisher methods we used. As suggested in Section 4 based on the growth accounting theory, to minimize the bias, we opt for the Törnqvist index approach in the aggregation that is not subject to the choice of the base year. The second panel of Table 5 reports estimates obtained by the Törnqvist aggregation approach with different deflators and deflation methods.

Let us start with the estimates by the single deflation approach with different deflators, all used in the CPV aggregation. We see that if using official deflators, there is little difference in the overall growth rate between the estimates by the single full-series Fisher deflation method of the CPV aggregation (9.3 percent per annum) and by the single deflation method of the Törnqvist aggregation (the same 9.3 percent). If changing to our deflators, the corresponding rates will be 8.5 and 8.7 percent, with the Törnqvist aggregation giving a growth rate at 0.2 ppts higher than the CPV approach. In the case of using the double deflation method, the estimates obtained by the Törnqvist aggregation also suggest a faster growth than those obtained by the CPV aggregation. With official deflators, the estimated annual growth rate will be 9.2 percent per annum by the former approach, compared to 8.9 by the latter, and if shifting to our deflators, it will be 8.3 and 7.8 percent, respectively. Therefore, the theoretically and methodologically sounder Törnqvist aggregation (Section 4) does not necessarily downward adjust estimates by other methods.

More importantly, as the coefficient of variation (c.o.v.) tests shown in the last column of Table 5, all the estimates using the alternative approaches have revealed greater volatility than the official estimates or their variants using different Laspeyres indices. However, the Törnqvist aggregation approach does not seem to exaggerate the volatility. Among all the alternative estimates, the volatility of the Törnqvist results remains around the average of the official (c.o.v.=0.286) and the CPV aggregation using the full-Fisher double deflation method with our deflators (c.o.v.=0.509), or a c.o.v. measure of 0.412. By revealing greater volatility, our recommended alternative approaches, especially the Törnqvist approach, are for the first time enable a better understanding of the true performance of the Chinese economy with invaluable information of volatility that has long been disguised in the official growth statistics.

TABLE 5

CHINA'S GROWTH PERFORMANCE REASSESSED: EFFECTS OF DIFFERENT DEFLATORS, DEFLATION AND AGGREGATION APPROACHES

(Annual GDP growth per annum)

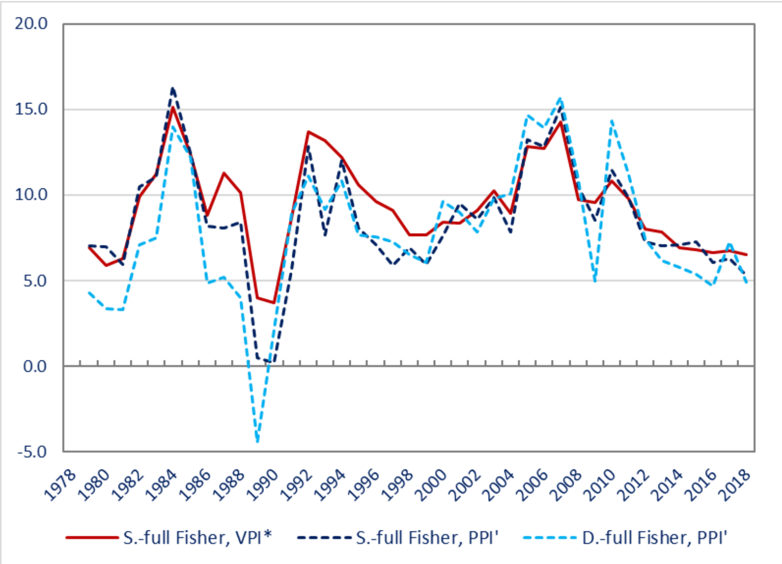
	1978-2018	1978-1984	1984-1991	1991-1996	1996-2001	2001-2007	2007-2012	2012-2018	*c.o.v.*[1]
Official, NBS (method unknown)	*9.5*	*9.3*	*8.9*	*12.4*	*8.3*	*11.3*	*9.4*	*7.0*	*0.286*
	Constant price values (CPV) aggregation[2]								
Official deflator (implicit VPI*=PPI*)									
…Single, Laspeyres 1985	*9.6*	9.2	8.8	12.8	8.5	11.6	9.7	6.8	*0.302*
…Single, Laspeyres 2015	*9.1*	9.3	8.2	11.1	8.0	11.2	9.4	7.0	*0.281*
…Single, segmented Fisher	*9.3*	9.2	8.6	12.1	8.2	11.3	9.5	7.0	*0.291*
…Single, full-series Fisher	*9.3*	9.2	8.4	11.9	8.2	11.4	9.6	6.9	*0.289*
…Double, segmented Fisher	*9.2*	8.6	7.8	11.4	8.0	12.8	9.9	6.6	*0.374*
…Double, full-series Fisher	*8.9*	5.9	7.2	11.2	8.2	13.7	10.5	6.2	*0.439*
Alternative deflator (PPI'=PPI adjusted)									
…Single, Laspeyres 1985	*8.8*	9.7	6.3	10.4	7.6	11.9	9.9	6.6	*0.384*
…Single, Laspeyres 2015	*7.7*	9.3	5.8	8.0	6.6	9.9	8.6	6.2	*0.399*
…Single, segmented Fisher	*8.5*	9.7	6.3	10.0	7.3	11.2	9.0	6.3	*0.392*
…Single, full-series Fisher	*8.5*	9.7	6.2	9.5	7.2	11.2	9.5	6.5	*0.388*
…Double, segmented Fisher	*8.1*	8.4	7.0	10.0	7.6	10.8	7.9	5.5	*0.429*
…Double, full-series Fisher	*7.8*	6.6	4.7	9.3	7.7	12.0	9.8	5.7	*0.509*
	Real growth rates aggregation[3]								
Official deflator (implicit VPI*=PPI*)									
…Single Törnqvist	*9.3*	9.1	7.5	11.5	8.5	11.9	9.9	7.1	*0.322*
…Double Törnqvist	*9.2*	10.1	7.6	11.1	7.7	12.1	9.5	6.4	*0.346*
Alternative deflator (PPI'=PPI adjusted)									
…Single Törnqvist	*8.7*	9.0	6.7	10.4	8.0	11.4	9.5	6.5	*0.377*
…Double Törnqvist	*8.3*	9.9	6.9	10.1	7.5	10.7	8.1	5.3	*0.412*
	Physical Indicator-based CPV aggregation[4]								
Revised Maddison-Wu, full-series Fisher[4]	*6.3*	6.9	4.5	8.3	4.9	9.1	6.8	4.2	*0.450*

Sources: The underlying nominal national accounts and price index data are estimated by the authors following the methodologies explained in Section 3.

Note: Growth rates are estimated by difference approaches explained in Section 4. 1) "c.o.v." is a simple coefficient of variation to test the dispersion of the entire series referred. 2) Aggregation is based on the value added of economy-wide 9 sectors at alternative constant prices. 3) Aggregation is based on the real growth rates of 37 industries encompassed by the 9 sectors, weighted by nominal weights. 4) Revised with updates in a national accounts framework with commodities aggregated by input-output table weights to index industrial growth, "non-material services" measured by numbers employed, and the rest of the economy adopting official index. See Wu (2013, 2014a, 2014b) for a revision of Maddison and Wu (2008).

In the following figures, we intuitively demonstrate the effects of alternative estimates on China's growth performance that may be attributable to the choices of deflators, deflation methods and aggregation approaches, as well as the differences in trend and volatility of these estimates. We can gauge two effects with the three series depicted in Figures 3 and 4. First, in Figure 3, by controlling for the full-series Fisher single deflation method, the disparity between the series using official deflators (VPI*) and the series with our alternative deflators (PPI') helps gauge a price effect. That is, if official deflators indeed underestimate price changes in the Chinese economy, how much the measured growth rate would be affected if instead using our alternative deflators. Furthermore, still exploring the results in Figure 3, by using the same alternative deflators (PPI'), the disparity between the series estimated by the full-series Fisher single deflation method and the series by the full-series Fisher double deflation method may indicate an effect of alternative deflation methods. Intuitively, the series by the double deflation method not only reveals greater volatility but pronounced the impact of the external shocks to the economy, more closely reflecting the reality than that by the single deflation method.

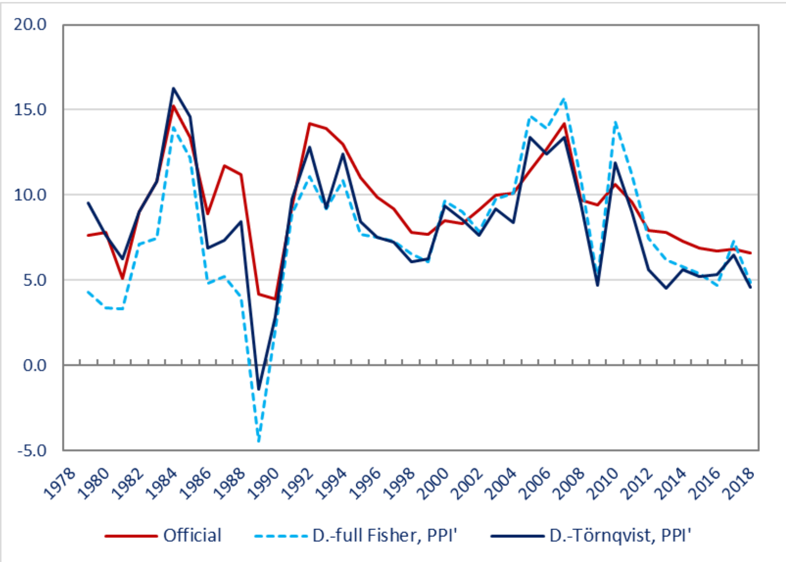
FIGURE 3
CHINA'S GROWTH PERFORMANCE REASSESSED:
EFFECTS OF DIFFERENT DEFLATORS AND DEFLATION METHODS
(Annual GDP growth in percent)



Source: Authors' estimates.
Notes: 1) S=single deflation, D=double deflation. See Section 4 for the Fisher index method. 2) VPI*=Official implicit GDP deflator. When using the single deflation method, that is, VPI*=PPI*=UPI*, where PPI* stands for official producer price index and UPI* for official user price index. 3) PPI' stands for the adjusted PPI constructed by this study.

Figure 4 is designed to further explore the aggregation effect. It keeps the series estimated by the full-series Fisher double deflation method, while bringing in the series by the Törnqvist aggregation approach as our preferred estimates. In addition, it also adds the original official or NBS series to compare with that of the Törnqvist approach. As expected, the Törnqvist approach corrects the possible biases underlying the CPV aggregation approach and provides results with somewhat less volatility. Comparing the two series, the one by the Törnqvist approach nonetheless not only maintains all the external shocks revealed by the CPV aggregation but highlights some macroeconomic changes in detail, emphasizing shocks in 1998 following the Asian financial crisis, in 2004 caused by a harsh austerity policy to control a feverish investment wave, and in 2012-2013 in the wake of the EU debt crisis. On top of these observations, the behavior of the official series appears to be more like that of a moving average of the alternative series especially since the 1990s, sacrificing or filtering all the information that is deemed critical in understanding as well as managing the macroeconomy and instead attempting to tell that all the "headline troubles" are not true.

FIGURE 4
CHINA'S GROWTH PERFORMANCE REASSESSED:
EFFECTS OF DIFFERENT AGGREGATION APPROACHES
(Annual GDP growth in percent)



Source: Authors' estimates.
Notes: 1) The "official series" is the annual reported growth rate by NBS without transparent methodological explanations. 2) PPI' stands for the adjusted PPI constructed by this study. 3) See Figure 3 for the abbreviation of deflation methods.

Volatility through sectoral lenses

In the last part of this section, we examine China's growth volatility through sectoral lenses based on our alternative estimates of average growth rates reported in Table 6 for the entire period and its subperiods and their dynamics underlying these average measures demonstrated in Figure 5. Facilitated by the charts, we find that the seemingly difficult-for-examination sectoral volatilities, especially those revealed by our preferred double deflation and Törnqvist aggregation approach, are actually able to help expose some reasonable sectoral behaviors associated with macroeconomic policy regime changes, external shocks, as well as market fundamentals in the Chinese economy.

In general, our preferred double deflation and Törnqvist aggregation approach with our alternative deflators unmasks greater volatility than other methods in many sectoral cases as presented in Table 6 and Figure 5. Let us begin with the agricultural sector in which we substitute official producer prices (VPI*=PPI*) for our adjusted producer prices (PPI'). With our approach, new negative shocks are exposed for 1994 and 2007, which result in a somewhat slower annual growth over the period 1978-2018 at 3.8 percent compared to the official rate at 4.4 percent. The corresponding degree of volatility is nonetheless opposite, at 0.715 and 0.575, measured as c.o.v. (Table 6).

The industrial sector, which is the key growth driver that led China's economic take off since the 1990s, is found more volatile with our approach than that with the official approach, especially following China's participation in the WTO. Also, to the surprise of many, except for the 1989 political shock, the volatilities we have discovered tend to pronounce peaks rather than troughs through the entire period in question (Figure 5), resulting in a higher annual growth rate at 12.4 percent compared to the official rate at 10.7 percent, with corresponding volatility at 0.545 and 0.407 (Table 6). This means that using apparently better deflator and sounder deflation and aggregation approaches, *ceteris paribus*, the role of China's industrial sector over the four decades could be bigger rather than smaller even if accompanied by a somewhat higher degree of volatility.

TABLE 6
CHINA'S GROWTH PERFORMANCE BY SECTOR: EFFECTS OF DIFFERENT DEFLATORS, DEFLATION AND AGGREGATION APPROACHES
(GDP growth per annum)

	1978-2018	1978-1984	1984-1991	1991-1996	1996-2001	2001-2007	2007-2012	2012-2018	*c.o.v.*[1]
Official deflator (single, method unknown)									
Total	*9.5*	*9.3*	*8.9*	*12.4*	*8.3*	*11.3*	*9.4*	*7.0*	*0.286*
…Agricultural	*4.4*	7.2	3.5	4.7	2.9	4.3	5.2	3.3	*0.575*
…Industrial	*10.7*	8.9	11.2	17.3	9.5	12.3	10.1	6.5	*0.407*
…Construction	*10.3*	10.5	9.4	14.7	5.7	13.1	12.3	6.8	*0.656*
…Wholesale, Retails	*10.4*	13.6	8.4	8.6	8.5	13.0	13.0	7.8	*0.785*
…Transport, Telecom.	*9.1*	8.4	10.4	10.6	9.9	10.1	7.2	6.9	*0.342*
…Hotel, Catering	*10.9*	15.3	11.2	15.9	9.3	11.9	6.6	6.3	*0.611*
…Financial Services	*12.4*	18.4	17.3	8.8	6.7	13.9	10.9	8.3	*0.773*
…Real Estate	*10.5*	8.4	18.1	13.2	7.2	13.0	6.5	5.2	*0.746*
…Other Services[2]	*10.7*	12.2	8.3	12.8	12.6	11.9	9.1	9.2	*0.285*
Alternative deflator (single, full-series Fisher[3])									
Total	*8.5*	*9.7*	*6.2*	*9.5*	*7.2*	*11.2*	*9.5*	*6.5*	*0.388*
…Agricultural	*4.4*	7.2	3.5	4.7	2.9	4.3	5.2	3.3	*0.575*
…Industrial	*10.2*	10.3	7.2	14.8	9.8	13.6	10.5	6.6	*0.453*
…Construction	*10.3*	10.5	9.4	14.7	5.7	13.1	12.3	6.8	*0.656*
…Wholesale, Retails	*10.8*	17.3	8.6	7.3	7.5	12.6	14.0	8.1	*0.663*
…Transport, Telecom.	*10.1*	11.2	8.1	10.8	6.5	13.3	9.5	11.3	*0.658*
…Hotel, Catering	*9.2*	0.3	13.8	14.8	15.5	13.4	1.7	4.7	*1.867*
…Financial Services	*12.7*	26.6	10.6	8.3	1.3	19.7	14.6	6.1	*1.014*
…Real Estate	*14.4*	22.7	19.6	12.1	16.4	15.1	9.1	3.9	*0.881*
…Other Services	*5.4*	8.7	4.9	5.2	5.2	4.9	3.6	5.1	*0.699*

Sources: The underlying national accounts in nominal terms and price indices are estimated by authors following the methodologies explained in Section 3.

Note: Growth rates are estimated by different deflation and aggregation approaches as explained in Section 4. 1) "c.o.v." is a simple coefficient of variation to test the dispersion of the entire series referred. 2) Including business services, non-market services (education, healthcare, and government) and personal services. 3) Single deflation with full-series Fisher price indices and constant price value aggregation are adopted.

TABLE 6 (CONT'D)
ASSESSING CHINA'S GROWTH PERFORMANCE BY SECTOR: EFFECTS OF DIFFERENT DEFLATORS, DEFLATION AND AGGREGATION APPROACHES
(GDP growth per annum)

	1978-2018		1978-1984	1984-1991	1991-1996	1996-2001	2001-2007	2007-2012	2012-2018	*c.o.v.*[1]
Alternative deflator (single, Törnqvist[4])										
Total	*8.7*		*9.0*	*6.7*	*10.4*	*8.0*	*11.4*	*9.5*	*6.5*	*0.377*
…Agricultural	*4.4*		7.2	3.5	4.7	2.9	4.3	5.2	3.3	*0.575*
…Industrial	*10.2*		8.7	7.5	15.1	10.1	13.7	10.9	6.8	*0.452*
…Construction	*10.3*		10.5	9.4	14.7	5.7	13.1	12.3	6.8	*0.657*
…Wholesale, Retails	*10.8*		17.3	8.6	7.3	7.5	12.6	14.0	8.1	*0.663*
…Transport, Telecom.	*10.0*		9.8	9.2	8.8	8.5	12.6	9.1	11.2	*0.532*
…Hotel, Catering	*9.2*		0.3	13.8	14.8	15.5	13.4	1.7	4.7	*1.867*
…Financial Services	*12.7*		26.6	10.6	8.3	1.3	19.7	14.6	6.1	*1.014*
…Real Estate	*14.4*		22.7	19.6	12.1	16.4	15.1	9.1	3.9	*0.881*
…Other Services[2]	*5.9*		8.0	5.1	5.7	7.2	5.1	4.3	5.8	*0.609*
Alternative deflator (double, Törnqvist[4])										
Total	*8.3*		*9.9*	*6.9*	*10.1*	*7.5*	*10.7*	*8.1*	*5.3*	*0.412*
…Agricultural	*3.8*		5.5	4.1	4.1	2.9	3.0	3.5	3.0	*0.715*
…Industrial	*12.4*		13.1	9.0	17.5	12.8	15.8	12.9	7.1	*0.545*
…Construction	*7.0*		7.0	15.0	5.6	3.0	10.8	1.2	3.1	*1.185*
…Wholesale, Retails	*10.9*		25.1	3.4	7.7	7.2	12.2	12.3	8.6	*1.259*
…Transport, Telecom.	*9.3*		10.6	7.7	8.2	4.1	12.8	10.3	10.6	*0.936*
…Hotel, Catering	*6.5*		-7.7	13.3	12.3	12.8	14.1	-0.9	1.5	*2.567*
…Financial Services	*11.0*		23.9	8.3	6.3	-1.0	17.4	14.1	6.4	*1.146*
…Real Estate	*11.5*		14.6	18.3	9.9	14.9	12.5	6.9	1.7	*1.105*
…Other Services[2]	*0.7*		3.9	3.5	1.2	-0.1	-2.6	-2.8	0.8	*7.257*

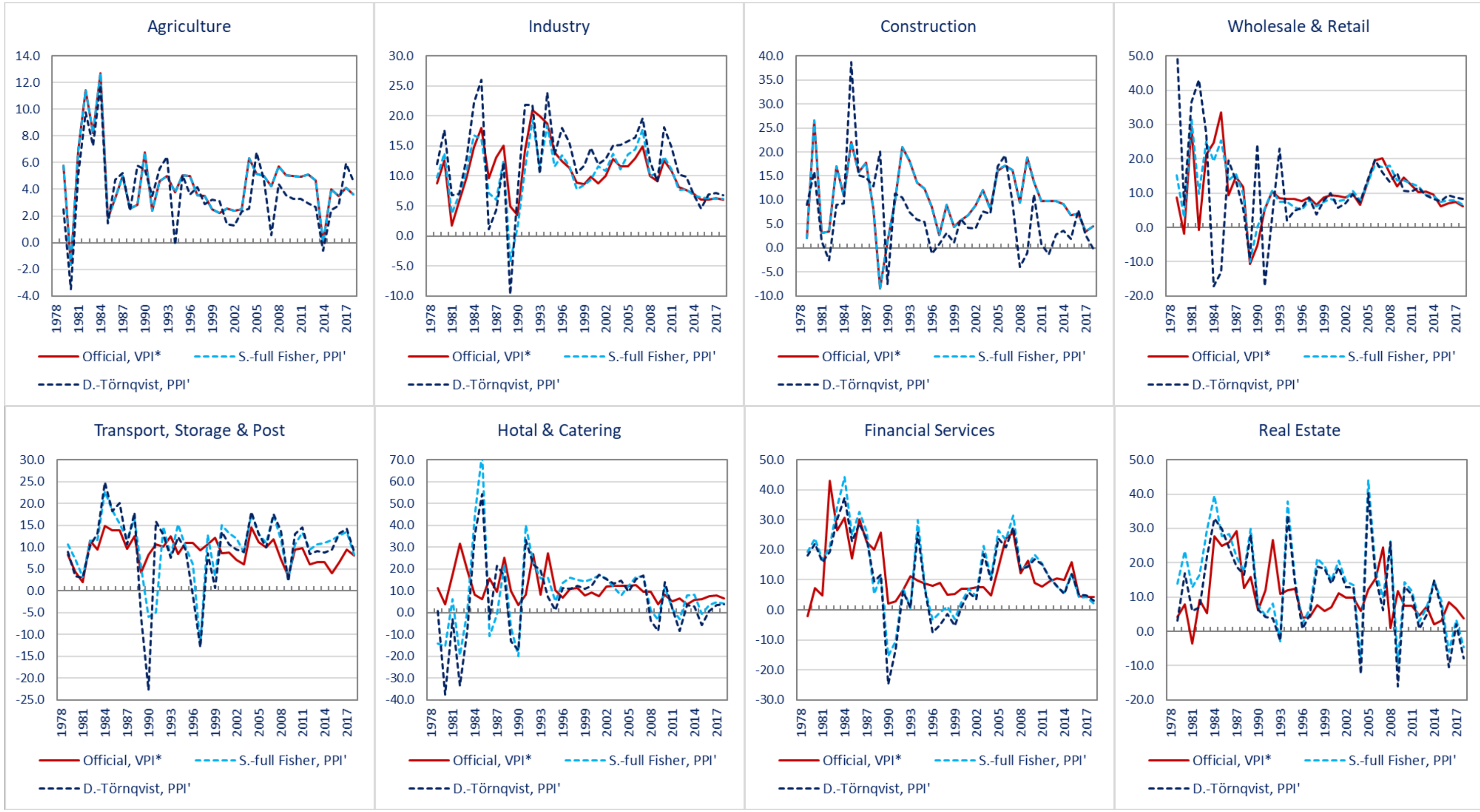
Sources: The underlying national accounts in nominal terms and price indices are estimated by authors following the methodologies explained in Section 3.

Note: Growth rates are estimated by different deflation and aggregation approaches as explained in Section 4. 1) "c.o.v." is a simple coefficient of variation to test the dispersion of the entire series referred. 2) Including business services, non-market services (education, healthcare, and government) and personal services. 3) Single deflation with full-series Fisher price indices and constant price value aggregation are adopted. 4) Törnqvist aggregation through weighted growth rates using either single or double deflation approach.

FIGURE 5

ASSESSING CHINA'S GROWTH PERFORMANCE BY SECTOR: EFFECTS OF DEFLATORS, DEFLATION AND AGGREGATION APPROACHES

(Change of GDP in percent)



Source: Authors' estimates.

Notes: The "other services" sector is dropped to save space. See Figure 3 for the abbreviation of deflation methods.

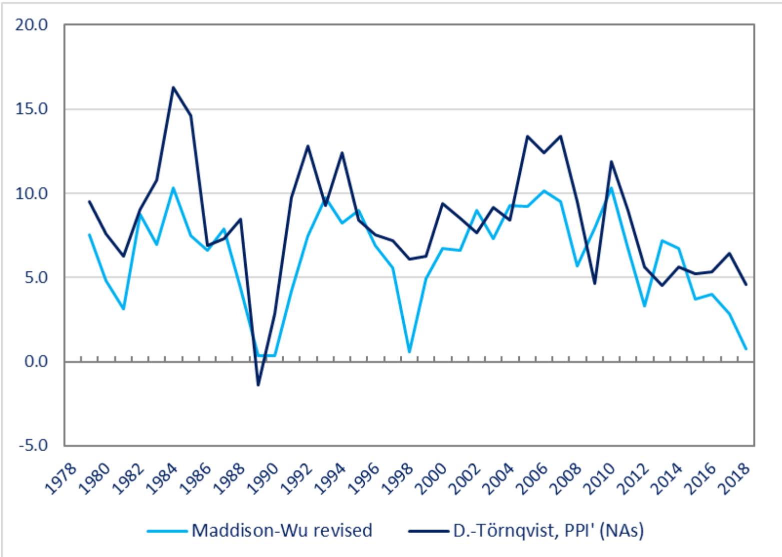
There are some sectors that are usually involved in government policies to sustain growth or to meet government growth target, of which the construction sector, the transport, storage, post and telecommunication sector, and the real estate sector in services were most affected. For the construction sector, with our approach, the known shocks in 2008 and 2012 become more pronounced, and the huge 1989 political shock was disclosed with a one-year delay, which is sensible due to the nature of the sector (Figure 5). These result in an annual growth estimate at 7.0 percent with a volatility at 1.185 in contrast to the official growth at 10.3 percent but accompanied with a much lower volatility at 0.656 (Table 6). The other two sectors behaved in a distinct manner in terms of responding to external shocks. Compared with estimates by the official approach, the transport, storage, post and telecommunication sector reveals greater troughs before the 2000s, yet only higher peaks afterwards; whereas the real estate sector exposes serious troughs since the mid-2000s that are completely disguised by the official approach (Figure 5).

Finally, we can use the wholesale & retail sector as an example to show the performance of sectors that is close to the end market. As shown in Figure 5, our estimation has surprisingly well tracked this sector since the 2000s as suggested by the official estimates, showing the lowest volatility among all sectors economy wide. This reflects that the nature of the sector is determined mostly by steady final consumptions. Yet its durable decline in the wake of the global financial crisis, from over 12 percent per annum in 2001-2007 to around 8 percent in 2012-2018, which is like that of the official estimates yet with much less volatility (Table 6), does not look like an encouraging sign that the economy is shifting to a more consumption-led growth as the government has best wished.

6. Concluding Remarks and Caveats

The popularly used physical indicator approach to assessing Chinese official growth estimates over the past three decades has put us in a dilemma obstructing the establishment of a common ground for researcher to communicate in a more productive way. We find that the system of national accounts is not only appealing but indispensable in dealing with the problem. In this study, with our reconstructed Chinese national accounts in time series and matching price indices, we address the biases in the official GDP data caused by the underestimated price changes because of methodological mishandlings of the deflation and aggregation problems of the national accounts. Our theory-based methodological procedures have not only exposed more volatile movements of, and greater impacts of negative shocks, to the economy, but also slower growth, contrary to what suggested by official statistics. We have estimated China's average GDP growth at 8.3 percent per annum for the entire period 1978-2018, which is 1.2 percentage points below the officially claimed rate at 9.5 percent. This implies that the accumulated real income over the past 40 years could be 36 percent smaller than what suggested by the official data. Besides, if tracking the underlying trend and comparing it with exposed volatilities, it suggests that China's WTO-induced faster growth is short lived because of the lack of fundamental support rather than that the government anti-cycle policies were not proper or effective enough.

FIGURE 6
CHINA'S GROWTH PERFORMANCE REASSESSED:
PREFERRED ESTIMATES VERSUS MADDISON-WU PHYSICAL INDICATOR INDEX
(Annual GDP growth in percent)



Sources: Maddison and Wu (2008), Wu (2013, 2014a and 2014b).
Notes: The reconstructed national accounts-based D-Törnqvist PPI' is the same as that in Figure 4. See "notes" to Figure 3 for the abbreviation of deflation and aggregation methods.

Can we make an appropriate comparison with any estimates using physical indicators? The work by Maddison and Wu (2008) is the most comparable because it is implicitly based on a framework of national accounts. In Wu's later revisions (2013 and 2014a), in addition to maintaining their employment-based treatment to the real output of "non-material services" (also see Wu, 2014b), their commodity-based, multi-input-output table weighted industrial index is improved in line with segmented Fisher approach and the real output of construction is estimated by changes of hour-adjusted employment rather than taking the official estimates for granted. A summary of the estimates is reported in the last panel of Table 5. In Figure 6, we compare the revised Maddison-Wu series with that of preferred in this study adopting the double deflation and Törnqvist aggregation approaches with our alternative deflators for China's national accounts.

As shown in the last panel of Table 5, the estimate by the Maddison-Wu approach suggests a much slower growth rate at 6.3 percent per annual for the whole period 1978-2018, that is, 2 ppts behind our estimate at 8.3 percent or 3.2 ppts behind the official estimate at 9.5 percent per annum. The factors behind these seemingly significant gaps, as shown in Figure 6, are likely the followings by speculation. The Maddison-Wu approach does not credit the high growth rates in the mid-1980s, the early 1990s, and the hey days of China's post WTO entry, whereas it suggests a greater negative shock both in the wake of Asian financial crisis in 1997-1998 and following the EU debt crisis in 2012, and a durable decline after 2015 when the government implemented a so-called "supply-side reform" to save the economy from its deeply rooted structural problems, yet unsuccessful. After the 1.2-ppt underlying price effect is removed from the official data, the rest 2-ppt gap may be speculated as attributable to institutional deficiencies. Despite that this is an important area in assessing China's real growth performance, it is out of the scope of this study.

We end this work by some necessary caveats that are hoped to invite constructive discussions. Our first caveat is that our CSY-reported annual GDP accounts with broad sectors and benchmark input-output tables may have lost some fine effects of structural changes. This may be to certain extent reflected by some of the counter movements between our estimates and those of following the Maddison-Wu approach, though the general trend of the two series is similar (Figure 6). Our second caveat is that our substitution of higher official nominal wage index for a much lower GDP deflator implicitly embedded in the GDP accounts for the sector of "other services" (education, healthcare and public administration, and personal services) has significantly lowered the contribution of this sector. This implies that these services are only produced by labor. We have no choice in the absence of a proper PPI for this sector, yet we are convinced that this choice is much closer to the reality than the official deflator. Our last caveat is about the bias that is likely caused by excluding the prices of imports due to lack of data, which may have affected our growth estimates for those industries that significantly rely on imported materials in inputs.

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