6401.0.60.004

Australian Bureau of Statistics

Information Paper

An implementation plan to maximise the use of transactions data in the CPI

Australia

2017

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AUSTRALIAN BUREAU OF STATISTICS

EMBARGO: 11.30AM (CANBERRA TIME) FRI 16 JUN 2017

ABS Catalogue No. 6401.0.60.004

Produced by the Australian Bureau of Statistics

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CONTENTS

PREFACE

Research over the past decade by National Statistical Offices (NSOs) and academics has identified opportunities for compiling price indexes from transactions data. As part of the program to enhance the Consumer Price Index (CPI), the Australian Bureau of Statistics (ABS) has investigated new methods, known as multilateral index number methods, to compile the Australian CPI. These new methods extend previous CPI enhancements that were implemented into the Australian CPI in 2014.

The ABS introduced CPI users to multilateral index methods to compile the CPI in the Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003). This publication assessed a selection of multilateral index methods against a framework comparable to the ABS Data Quality Framework (DQF); and provided empirical results. Findings from this work demonstrated support for using a multilateral method in the Australian CPI, but did not recommend a specific method.

The international price statistics community has reached a consensus that multilateral methods are the most effective way to exploit the full amount of information provided in transactions datasets. Further, in light of additional research and external consultation with key stakeholders and international experts, the ABS is now in a position to make an informed decision about the type of multilateral index method to implement into the Australian CPI.

This information paper provides the plans for implementation of a multilateral method into the CPI. It explains the choice of method and aggregation structure, and concludes with a timeline for implementation.

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EXECUTIVE SUMMARY

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This information paper presents methodological changes for the use of transactions data to compile the Australian Consumer Price Index (CPI). The methods recommended in this paper are planned to be implemented into the CPI from December quarter 2017.

The implementation of these new methods would represent a significant enhancement to the Australian CPI. This includes using all the products available in the datasets (rather than a sample of products) and weighting products by their economic importance (rather than using unweighted price indexes). The use of multilateral methods will require fewer resources in the medium term.

Extensive consultation with international experts and key stakeholders has been undertaken to secure support for these enhancements; and to manage statistical risk. Implementation of these enhancements will occur in the December quarter 2017. Consultation included external expert reviews by Professor Kevin Fox and Professor Jan de Haan; and a stakeholder engagement program including a call for public submissions. The ABS also conducted numerous bilateral and multilateral consultations with key stakeholders, including: the Reserve Bank of Australia; the Treasury; Department of Social Services; Department of Finance; and State Treasuries.

Transactions (scanner) data refers to point-of-sale purchases from retailers and is currently used to compile approximately 25 per cent of the CPI weight. The ABS currently uses a 'direct replacement' of observed point-in-time prices with a unit value calculated from the transactions data. The international price statistics community has reached a consensus that new methods, called multilateral methods, are the most effective way to exploit the full amount of information provided in transactions datasets. The forthcoming update of the International Labour Organization (ILO) Consumer Price Index Manual will recommend the use of multilateral methods for temporal aggregation when using transactions data.

As part of the ABS research program into Enhancing the CPI, a number of multilateral methods have been considered for implementation into the CPI. This research assessed a selection of multilateral index methods against a framework comparable to the ABS Data Quality Framework (DQF); and provided empirical results. In light of additional research and external consultation and review[1], including with international experts, the ABS is now in a position to make an informed decision regarding the implementation of multilateral methods. This information paper provides the plans for implementation and the methodological details of these changes.

The methods discussed in this paper will be used to compile 28 Expenditure Classes (ECs) in the Australian CPI. The historical analysis presented in this paper indicates this methodological change would have had a minor downward impact on the overall CPI. This may not translate into a similar result in future periods.

In summary, the specific methods to be implemented by the ABS to compile the CPI from transactions data are:

- GEKS-Törnqvist as preferred multilateral method compiled using respondent classes as EAs.
- Weighted Time Product Dummy (TPD) method to be run concurrently (for comparison purposes).

1 See appendices 1 and 2.

EXECUTIVE SUMMARY
continued

- Aggregate EAs together using Törnqvist index formula to form respondent indexes.
- Aggregate respondent indexes together using Lowe Index formula.
- Mean splice extension method with a rolling window of 9 quarters

The following is a timetable for implementation:

- ABS to continue to monitor these methods during June quarter 2017 and September quarter 2017; and make refinements as required.
- ABS to implement new methods in December quarter 2017. This is to align the implementation of multilateral methods with the introduction of updated household expenditure data for weighting purposes[2].

2 See Information Paper: An Implementation Plan to Annually Re-weight the Australian CPI (cat. no. 6401.0.60.005)

INTRODUCTION

1.1 The Australian Bureau of Statistics (ABS) Consumer Price Index (CPI) is a robust measure of household inflation, providing trusted official statistics to the Australian community for nearly 70 years. The CPI uses internationally endorsed methods, and aims to build on this by exploiting opportunities to use big data for compiling official statistics. In the environment of delivering the best possible statistical programs in more efficient and innovative ways, the ABS has undertaken a research program investigating priorities to enhance the CPI. This publication focuses on one component of that program, that being to maximise the use of transactions data to compile the Australian CPI.

1.2 Transactions (scanner) data refers to point-of-sale purchases from retailers and contains detailed information about transactions, dates, quantities, product descriptions, and values of products sold. From March quarter 2014 the ABS significantly increased its use of transactions data to compile the Australian CPI, now accounting for approximately 25 per cent of the weight of the Australian CPI. The approach adopted was a 'direct replacement' of observed point-in-time prices with a unit value calculated from the transactions data.[3]

1.3 While the implementation of this method represented an improvement over traditional CPI practices (e.g. average unit value replaced a point-in-time price), further enhancements are possible. This includes using all the products available in the datasets (rather than a sample of products) and weighting products by their economic importance (rather than using unweighted price indexes). Ideally, National Statistical Offices (NSOs) can achieve both these improvements using automated processes with minimal manual intervention.

1.4 One option for using timely expenditure information available in transactions datasets is the calculation of weighted bilateral indexes (e.g. Fisher, Törnqvist). Weighted bilateral indexes compare prices and expenditure across two points in time. They treat expenditure patterns symmetrically and can be compiled either directly or indirectly (chained). Unfortunately, both these bilateral approaches have shown weakness when applied to transactions data.

- Direct bilateral indexes compare prices and quantities from the current period relative to an earlier base period (e.g. period 0 to 1, period 0 to 2). They have the problem of item attrition (i.e. product entries and exits) decreasing the amount of matched products overtime. Additionally, the period chosen as the base period is given special importance and will exclude some items (e.g. seasonal items) that are not available in the base period (Diewert 2013).
- Indirect (chained) bilateral price indexes compare prices and quantities from consecutive time periods (e.g. period 0 to 1, period 1 to 2) which can be chained together to form a continuous series. While indirect bilateral methods address the item attrition issue observed with direct comparisons, they suffer from a 'chain drift' problem where the index fails to return to parity after prices and quantities revert back to their original values. 'Chain drift' is caused by quantities spiking when consumers stock up goods that are on sale, and not returning to their normal level immediately after the sales period (Ivancic, Fox and Diewert 2011; van der Grient and de Haan 2011).

3 Introduction of Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) provides a more detailed explanation of current ABS methods used with transactions data.

1.5 The limitations of traditional bilateral index formulae have motivated research by NSOs and academics into new methods for compiling price indexes from transactions data. Typically, multilateral index methods have been used in the spatial context to compare price levels across different regions, however academics and NSOs are proposing they be used to make price comparisons across multiple (three or more) time periods. Multilateral methods have a number of advantages for temporal aggregation including:

- Using a census of products available in datasets;
- Weighting products by their economic importance; and
- Producing price indexes that are free of chain drift.

1.6 Statistics Netherlands (Chessa 2016) and Statistics New Zealand (SNZ 2014) are currently the only NSOs compiling components of their respective CPIs using multilateral methods. The Consumer Price Index Manual (ILO 2004) is in the process of being revised to include material recommending the use of multilateral methods for temporal aggregation when using transactions data (Dippelsman and Diewert 2017). Where appropriate, the ABS will contribute information to the update of the revised Consumer Price Index Manual.

1.7 When a multilateral method is used to produce a temporal index, each bilateral price comparison depends on prices observed in other periods of the multilateral comparison window. As a result, incorporating a new period into the multilateral comparison window may alter the price comparisons of earlier periods. To overcome the issues of revisions and produce a CPI in 'real time', NSOs must choose an extension method to use in a production setting.

1.8 As part of the ABS research program into Enhancing the CPI, a number of well-known multilateral and extension methods have been considered for use in the CPI. This research assessed different multilateral methods against a framework associated with the ABS Data Quality Framework (DQF) and was supported by empirical evidence to observe how methods behaved in practice. While this work demonstrated support for using a multilateral method in the Australian CPI, it did not recommend a specific method for the ABS. In light of further research and external consultation with CPI stakeholders and international experts, the ABS is now in a position to provide details on the preferred methods for using transactions data in the CPI.

1.9 The remainder of this publication provides on an implementation plan for maximising the use of transactions data in the CPI. Section two of this paper describes the specific methods the ABS will use in the production of the CPI. The justification for choice of methods borrows heavily from the framework established for assessing multilateral methods in the Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) as well as supporting empirical evidence. Section three provides empirical results comparing the published CPI to price indexes produced using a multilateral method. The remaining sections detail consultation conducted by the ABS and a planned timeline for implementation into the Australian CPI.

METHODS FOR COMPILING TRANSACTIONS DATA

BACKGROUND

2.1 Multilateral methods possess a number of desirable qualities, both theoretical and practical, to produce temporal price indexes from transactions data. This section details the practical and methodological decisions for aggregating transactions data in four sub-sections: aggregation structure, multilateral method, extension method and multilateral window length. This publication returns to the framework established in the Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) which linked the ABS Data Quality Framework (DQF) to six main criteria for an NSO to evaluate different multilateral methods (Table 2.1).

TABLE 2.1: FRAMEWORK FOR ASSESSING MULTILATERAL METHODS

Consideration	*Quality dimensions*
Resources: does this method help facilitate more effective use of human and information resources?	Institutional Environment, Timeliness
Theoretical properties: what conceptual properties does the index method have, and how well do these align with the CPI purpose?	Accuracy
Transitivity: to what extent is the index transitive?	Accuracy, Coherence
Characteristicity: to what extent are price comparisons relevant to the time periods being compared?	Accuracy, Relevance
Flexibility: what scope is there to use or adapt the method for new statistical products or data sources?	Coherence, Institutional Environment
Interpretability: how easy is it to understand the method and the price movements it calculates?	Interpretability

2.2 For an NSO to implement new methods using transactions data, it is necessary to describe how changes will be harmonised with existing data sources and methods used in the CPI. At the lowest level, a NSO must define a homogeneous item and how unit values will be aggregated across time, retailer and region. At a higher level, elementary aggregation must occur where prices are combined to produce price indexes that must be combined with other components in the CPI. Operational decisions about how multilateral methods will be implemented into the wider CPI collection will be discussed below in the aggregation structure sub-section.

2.3 The ABS has previously conducted research into four multilateral methods for implementation into the CPI. Empirical findings showed that different multilateral methods typically produced similar results in practice which is consistent with other research findings (Ivancic, Fox and Diewert 2011; Chessa, Verburg and Willenborg 2017). The multilateral method sub-section will detail the preferred method for the Australian CPI based on the framework described in Table 2.1.

2.4 Practical challenges exist when applying multilateral methods in a production setting. When a multilateral index is extended by an additional period (e.g. quarter), previous price movements are revised, which is unacceptable for NSOs. To deal with this revisions problem, the ABS will implement an extension method to compile the CPI which is described in the extension methods sub-section.

BACKGROUND *continued*

2.5 Finally, the decision to implement a multilateral method requires a NSO to specify the number of time periods used for each set of price comparisons. Most research has recommended a minimum of one year plus one period (i.e. five quarters) to account for seasonal availability of products. The estimation window sub-section will detail the preferred estimation window size for the Australian CPI.

AGGREGATION STRUCTURE

Product definition

2.6 The definition of a homogeneous product where the calculation of a unit value occurs will largely remain consistent with current practices in the CPI. The ABS will continue to define products using product classifications provided by Australian proprietors known as the stock keeping unit (SKU). The unit value will continue to be calculated using expenditure and quantity information across all stores from the same proprietor for each capital city in Australia (e.g. Company 1 for Sydney).

2.7 The unit value will be calculated on a quarterly frequency to align with the publication frequency of the Australian CPI. This differs slightly with current CPI practice, where unit values are derived at both monthly and quarterly frequencies for practical reasons (e.g. consistent with other modes of collection). Research has shown that the unit value calculation should align with the publication frequency of the CPI (Diewert, Fox and de Haan 2016).

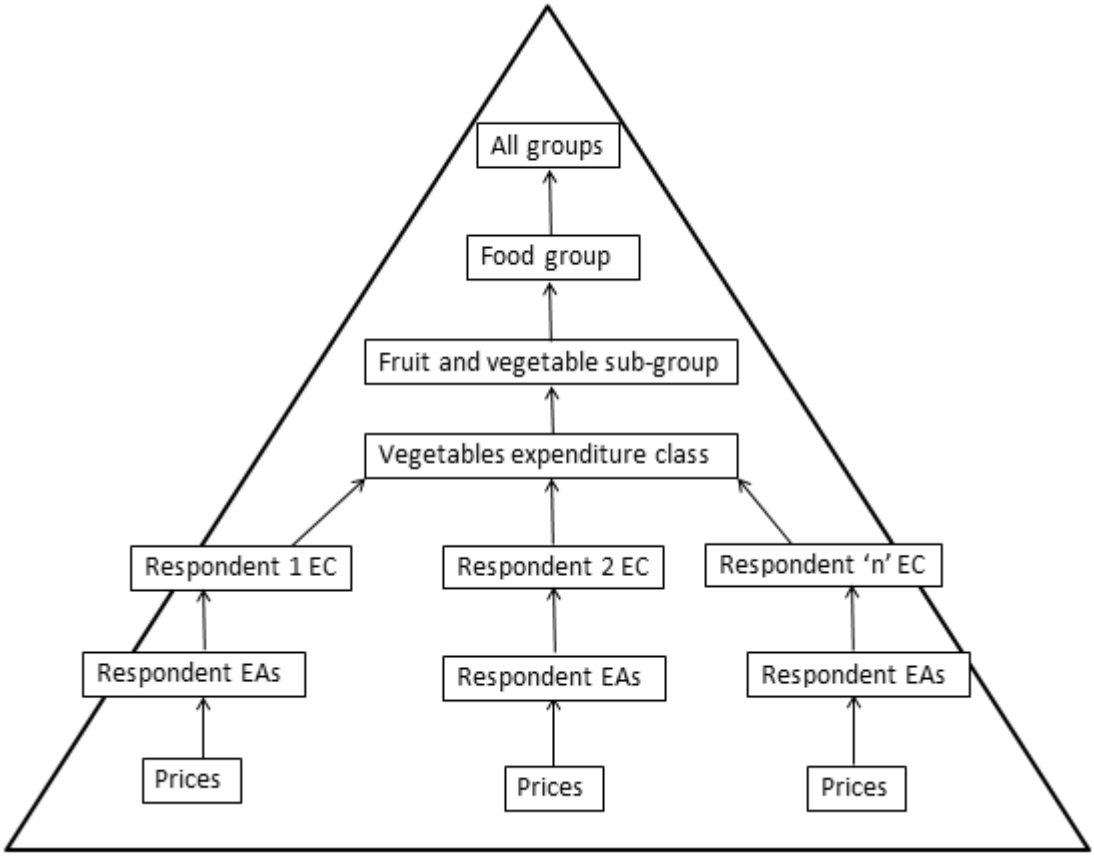
2.8 The calculation of the unit value should occur across products that are considered equivalent from the perspective of a consumer. Research by other NSOs has shown that matched model multilateral indexes can have a downward bias if price increases are missed when the same item is 'relaunched' using a different product identifier (Chessa 2016). The issue of relaunches is a known problem when identifying products using barcodes for certain commodities, while the choice of a broader product definition such as SKU (which is an aggregation of multiple barcodes) should mitigate this problem. The ABS will continue to monitor the suitability of defining products using the SKU.

Elementary aggregation

2.9 Following the definition of a product, elementary aggregation (i.e. aggregating prices to form price indexes) can be performed using a multilateral method. The Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) presented empirical evidence using a modified aggregation structure that aggregated prices directly to the EC level for each respondent using a multilateral method. Peer review received by the ABS highlighted that some ECs contain relatively heterogeneous items, and that performance of the multilateral method could be improved by compiling multilateral methods below the EC level. Compiling multilateral methods below the EC level is consistent with practices adopted by other NSOs (Dalén 2017; Chessa 2016).

2.10 The ABS has conducted further research into compiling multilateral methods below the EC level using respondent classifications provided within transactions datasets. Figure 2.1 details an aggregation structure for implementation in the CPI, which uses respondent classes as elementary aggregates (EAs) when these are available from transactions datasets. The Törnqvist index formula will be used to aggregate respondent EAs together to compile 'Respondent x EC' price indexes in order to capture changes in consumer expenditure patterns overtime. 'Respondent x EC' indexes will be weighted by expenditure (market) share using the Lowe Index formula, with weights being reviewed on an annual basis using both transactions and other data sources.

FIGURE 2.1 AGGREGATION STRUCTURE



Elementary aggregation continued

2.11 The aggregation structure in Figure 2.1 produced very similar time series compared to aggregation direct to the EC level as presented in the Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003), since both aggregation structures use expenditure weights at the product level. Despite a negligible empirical difference, the structure in Figure 2.1 is preferred as it ensures coherence with traditional elementary aggregation in the CPI whilst utilising each respondent's expenditure information using the Törnqvist index formula.

2.12 The structure described in Figure 2.1 includes contributions from transactions data respondents only. This structure will be used to compile price indexes for 28 ECs (list provided in paragraph 2.20). The motivation to compile these ECs using transactions data only is based on evidence of high expenditure (market) share, as well as the resources required to maintain a high quality non-transactions data index component. Moving forward, the ABS will monitor the suitability of the ECs using transactions data only.

MULTILATERAL METHOD

2.13 As discussed in section one, multilateral methods offer advantages to NSOs where price indexes can be compiled using a census of all products whilst producing weighted price indexes that are free of chain drift. The Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) conducted research into the following four methods for potential implementation into the Australian CPI[4]. These methods were:

4 Multilateral Methods of the Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) provides a more detailed explanation of these multilateral

MULTILATERAL METHOD *continued*

- Weighted Time Product Dummy (TPD)
- Geary-Khamis (GK)
- Quality adjusted unit value using TPD (QAUV_TPD)
- GEKS-Törnqvist[5]

2.14 One way to assess the accuracy/performance of multilateral methods is to evaluate it against a set of desirable properties. This is known as the test approach. The Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) identified that no multilateral method passed all the tests proposed by Diewert (1999) and Balk (1996, 2001), meaning that the importance placed on each test would dictate the preferred multilateral method.

2.15 The Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) also assessed multilateral methods from the economic approach to index numbers. This approach assumes consumers optimise their basket of purchases to minimise cost for a given level of utility. It identified that the GEKS-Törnqvist method is exact for a "flexible" functional form - that is, it expresses the price differences experienced by optimising consumers without imposing restrictive assumptions about how they can substitute between products (Diewert 1999). In contrast, the GK method and other additive methods are consistent only with either perfect substitution or perfect non-substitution, so they may suffer from substitution bias if consumer preferences are more complex. At the time of the information paper, the TPD and QAUV_TPD methods had not been assessed rigorously from the economic approach.

2.16 Recent work by Diewert and Fox (2017) has assessed the TPD, GK, QAUV_TPD and the GEKS-Törnqvist from the economic approach to index numbers. This work established that the TPD is an approximately additive method that is consistent with linear and Cobb-Douglas preferences, while the QAUV_TPD shares the same economic assessment as the GK method. Using a simulated dataset to mimic the characteristics observed in transactions data, the authors show that in certain circumstances the TPD and GK can diverge from indexes that are free from substitution bias.

2.17 In terms of the other criteria described in Table 2.1, all four multilateral methods have the flexibility to deal with different types of data sources (e.g. data without weighting information, data with characteristic information). With respect to interpretability, the GEKS-Törnqvist has a slight advantage in that it is based on traditional price index theory - as the multilateral movements are derived by combining superlative bilateral indexes.

2.18 Testing the different multilateral methods in practice, the ABS found little difference and no clear indication of substitution bias for the TPD, GK and QAUV_TPD. The Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) found evidence that when the multilateral methods temporarily diverged, it was due to the GEKS-Törnqvist use of average matched expenditure shares to weight the importance of products. Other authors (Chessa, Verburg and Willenborg 2017; Diewert 2013) have drawn similar conclusions,

methods.

5 This method is also known as CCDI attributed to the authors Caves, Christensen and Diewert (1982) and Inklaar and Diewert (2017).

MULTILATERAL METHOD *continued*

demonstrating that the GEKS-Törnqvist can be sensitive to products that have periods with atypical prices and very small quantities (clearance prices). In these instances, the other multilateral methods may have an advantage over the GEKS-Törnqvist.

2.19 Weighing up the above considerations, the ABSs preferred method for compiling price indexes using transactions data is the GEKS-Törnqvist. While the different multilateral methods produce similar results, the two main criteria that differentiate the GEKS-Törnqvist from the other multilateral methods are its theoretical properties (economic approach to index numbers) and interpretability (based on bilateral index number theory). To remedy the sensitivity of the GEKS-Törnqvist to products with atypical prices and small quantities (clearance prices), the ABS will refine its methods to detect and exclude these products from index compilation. The exclusion of products at clearance prices is consistent with current practices adopted in the CPI.

2.20 The list below details the ECs which will use the GEKS-Törnqvist as the aggregation method where transactions data are available. These 28 ECs account for approximately 17 per cent of the CPI weight as of March quarter 2017.

ECs using multilateral methods:

- Beef and veal
- Bread
- Breakfast cereals
- Cakes and biscuits
- Cheese
- Cleaning and maintenance products
- Coffee, tea and cocoa
- Eggs
- Fish and other seafood
- Food additives and condiments
- Fruit
- Ice cream and other dairy products
- Jams, honey and spreads
- Lamb and goat
- Milk
- Oils and fats
- Other cereal products
- Other food products n.e.c.
- Other meats
- Other non-durable household products
- Personal care products
- Pets and related products
- Pork
- Poultry
- Snacks and confectionery
- Tobacco
- Vegetables
- Waters, soft drinks and juices

EXTENSION METHOD

2.21 When multilateral methods are used to produce a temporal index, each bilateral price comparison depends on prices observed in other periods of the multilateral comparison window. As a result, incorporating a new period into the multilateral comparison window may revise previous price indexes, which is unacceptable for CPI purposes. To resolve this, researchers have developed methods for using the latest multilateral index incorporating the latest data to update the published index series.

2.22 The Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) considered four methods for extending the index series. These can be characterised into the following two groups[6]:

- The *direct (annual) extension*[7] method proposed by Chessa (2016). This involves extending the multilateral estimation window from some (annually) fixed base period as each new period becomes available, and using the price change between the base period and the new period to extend the series.
- *Rolling window methods* inspired by Ivancic, Diewert and Fox (2011), which all involve calculating a new multilateral index using a window of fixed length as each new period becomes available. Having chosen some splice period common to the current and previous windows, the series is extended using the ratio of the price change between the splice period and the current period (using the current window) and the price change between the splice period and the previous period (using the previous window). Choosing the splice period to be the previous period yields a movement splice (Ivancic, Diewert and Fox 2011); choosing the start of the current window yields a window splice (Krsinich 2016); choosing the midpoint of the current window yields a half splice (de Haan 2015). Algebraically, the published index movement from the previous period (t-1) to the current period (t) can be expressed as:

$$P^{t-1,t} = \frac{P_M^{s,t}(current)}{P_M^{s,t-1}(previous)}$$

where:

$P_M^{s,t}(current)$ = price movement between the splice period s and t based on the current multilateral window

$P_M^{s,t-1}(previous)$ = price movement between s and t-1 based on the previous multilateral window

2.23 The Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) found that the indexes extended using the direct method can be influenced by the choice of link month. Although these indexes seem plausible in the long term, their price movements soon after the link period are based on only a few periods of data, which can make them more volatile than index movements later in the window. Lamboray (2017) suggests a hybrid fixed-base rolling window approach which may address this issue: this is an area for further research. For the moment, however, the ABS decided not to adopt the direct (annual) extension method.

6 Multilateral Extension Methods of the Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) provides a more detailed explanation of these extension methods.

7 This method is named the Fixed Base Moving Expansion (FBME) by Chessa, Verburg and Willenborg (2017).

EXTENSION METHOD *continued*

2.24 The Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) compared rolling window splicing methods and found that the movement, window and half splice indexes were often similar. On balance, however, the half splice indexes were most often (but not always) the closest to the reference "full" index which incorporated no splicing, with other splicing methods displaying a degree of drift.

2.25 A likely cause of this drift is systematic price changes immediately after products appear or disappear that reflects the product's age rather than actual inflation. For instance, where products tend to appear at prices that are (in retrospect) higher than normal or disappear at prices that are lower than normal. This can result in downward quality adjustment bias. As Krsinich (2016) and de Haan (2015) argue, the window splice mitigates this bias for new products by implicitly revising the contributions of new products to the index as more of their prices become available. However, this implicit revision makes the window splice sensitive to the price changes of disappearing products, as the current window has less information about their normal prices than the previous window. Conversely, the movement splice mitigates quality adjustment bias for disappearing products but will be sensitive to new products. The half splice is a reasonable compromise between the two.

2.26 Since the Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003), Diewert and Fox (2017) have tested a "mean splice" rolling window method - initially proposed by Ivancic, Diewert and Fox (2011) - which involves extending the index using the geometric mean of the indexes produced from all possible choices of splice period. Using the notation above, the mean splice extension can be expressed algebraically as

$$P^{t-1,t} = \prod_{s=t-T}^{t-1} \left[\frac{P_M^{s,t}(current)}{P_M^{s,t-1}(previous)} \right]^{\frac{1}{T}}$$

where the multilateral window length is $T+1$ periods, so the current and previous periods overlap between *t-T* and *t-1*. It can be shown that the mean splice effectively makes a small implicit revision to price movements early in the current window and a large implicit revision to price movements later in the current window. This mitigates the effect of both new and disappearing products, similar to the half splice.

2.27 Empirical testing suggests that the half and mean splice methods produce comparable indexes. A typical example is shown in Figure 2.2 below which compares GEKS-Törnqvist indexes with different splicing methods using a nine quarter estimation window. Since these results are at the respondent level, all splicing methods have been standardised (i.e. period 0 corresponds to an index level of 100), and are then expressed relative to the mean splice index (e.g. Movement splice (MS) = MS index less mean splice index). The results show that the mean and half splice (HS) are the closest in proximity (within 0.5 index points), while the movement (MS) and window splice (WS) deviate from the mean splice by a larger amount in opposite directions. Figure 2.3 shows an example where the half splice (HS) deviates a larger magnitude from the mean splice.

EXTENSION METHOD *continued*

FIGURE 2.2: CAKES AND BISCUITS EC

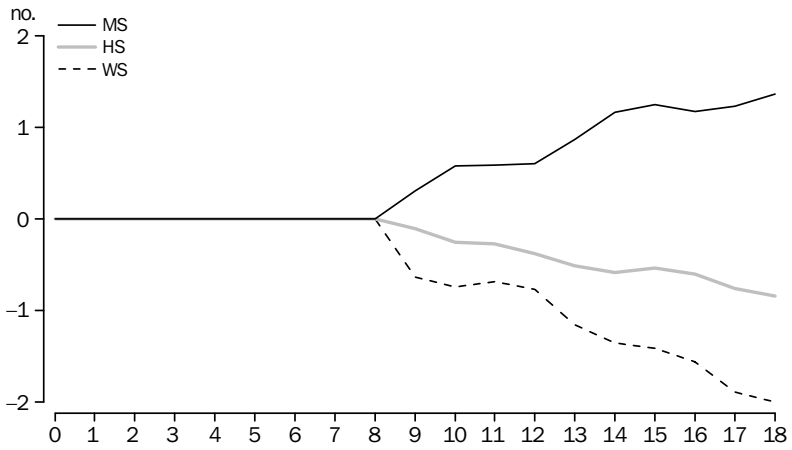
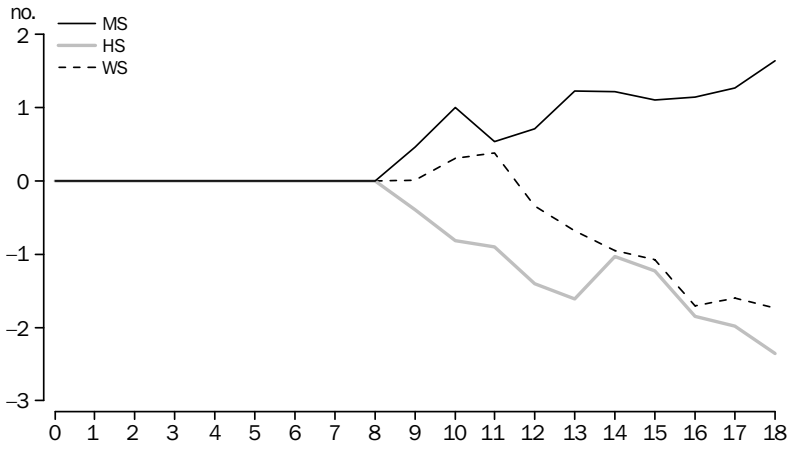


FIGURE 2.3: FRUIT EC



2.28 In summary, the ABS will use the mean splice. This is motivated by several factors:

- Conceptually, it seems more natural to make the results independent of the choice of splice period by using all the periods they have in common, rather than choosing a single splice period.
- Empirically, the mean splice appears more robust - while the half splice mitigates systematic quality adjustment bias, choosing an alternative splice period close to the midpoint can give quite different results.
- The mean splice has appealing properties in the long term - this is an area for further study

MULTILATERAL WINDOW LENGTH

2.29 The decision to implement a multilateral method requires an NSO to specify the number of time periods used for price comparisons. Most research using rolling window approaches has recommended a minimum of one year and one period (i.e. five quarters, 13 months) to account for products seasonal availability, though there is currently no consensus on the optimal length of the multilateral window.

2.30 The choice of multilateral window length is a trade-off between two criteria described earlier in Table 2.1 - characteristicity and transitivity. If the multilateral window is too long then the index could suffer from a loss of characteristiciy where price change in the past may disproportionally impact recent inflation estimates. If the multilateral

MULTILATERAL WINDOW LENGTH *continued*

window is too short, the index may suffer from the 'chain drift' problem. Empirical testing of different window sizes is necessary to assist with this decision.

2.31 Results presented in the Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003) used a window size of two years and one period (i.e. nine quarters, 25 months) as the preferred window length - this was based on empirically testing various estimation windows compared to each other (as well as their proximity to different "full" price series). Empirical testing by the ABS showed that varying the length of the estimation window generally made little difference to the price series generated. When the series did diverge the use of a shorter window (i.e. one year and one period) tended to display more downward (upward) drift if the series showed a decreasing (increasing) price trend. This publication continues with recommending a window size of two years and one period for the length of the multilateral window.

EMPIRICAL RESULTS

3.1 Empirical results at the published level are presented below for a selection of indexes which combine the price movements of both transactions and non-transactions data respondents. The figures plot both the published CPI and the CPI with the GEKS-Törnqvist index to measure the statistical impact of the methodological changes proposed in this publication. The time series produced covers the periods December quarter 2013 to March quarter 2017 for the weighted average of Australia's eight capital cities.

3.2 Figure 3.1 plots the published CPI and the CPI (GEKS-Törnqvist) at the All Groups level. Across the analysis period, the proposed changes had a minor downward impact on inflation where the CPI reported a price increase of 5.4 per cent while the CPI (GEKS-Törnqvist) reported a smaller rise of 5.3 per cent. In terms of quarterly percentage change, Figure 3.2 plots both series with the largest divergence occurring in September quarter 2016 due to the CPI (GEKS-Törnqvist) reporting lower inflation for the Fruit EC.

FIGURE 3.1: ALL GROUPS PRICE INDEX

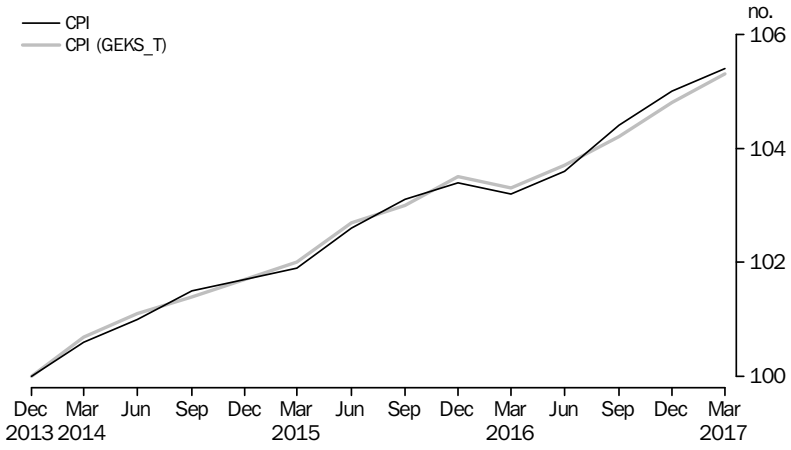
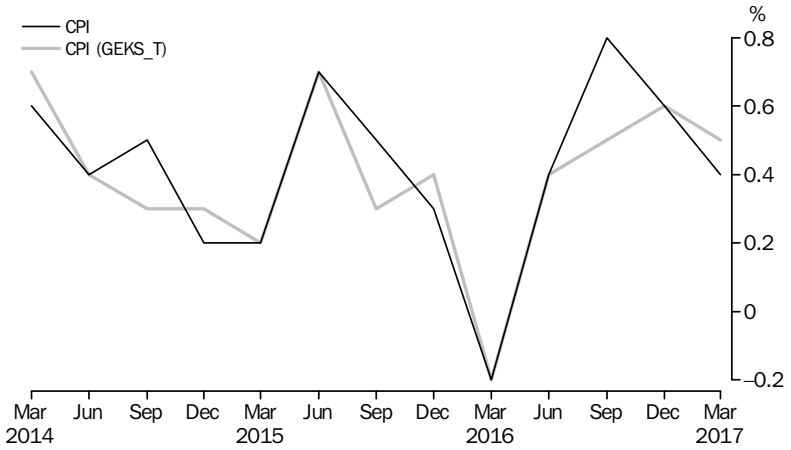


FIGURE 3.2 ALL GROUPS QUARTERLY PERCENT CHANGE



3.3 The following eight figures compare the published CPI and CPI (GEKS-Törnqvist) at the sub-group level where transactions data exhibits a large expenditure (market) share. Figure 3.3 plots price indexes for the Tobacco sub-group, where the CPI reported a rise of 52.9 per cent while the CPI (GEKS-Törnqvist) reported a larger rise of 57.8 per cent

EMPIRICAL RESULTS
continued

across the analysis period. The divergence between the two series is due to the CPI (GEKS-Törnqvist) capturing a higher expenditure weight for cheaper tobacco products that experienced larger price rises relative to more expensive tobacco products as a result of taxation increases on tobacco products. Figure 3.4 plots the quarterly percentage change – the results are very similar with the largest divergence occurring in December quarter 2014 following the biannual increase to the tobacco excise.

FIGURE 3.3: TOBACCO PRICE INDEX

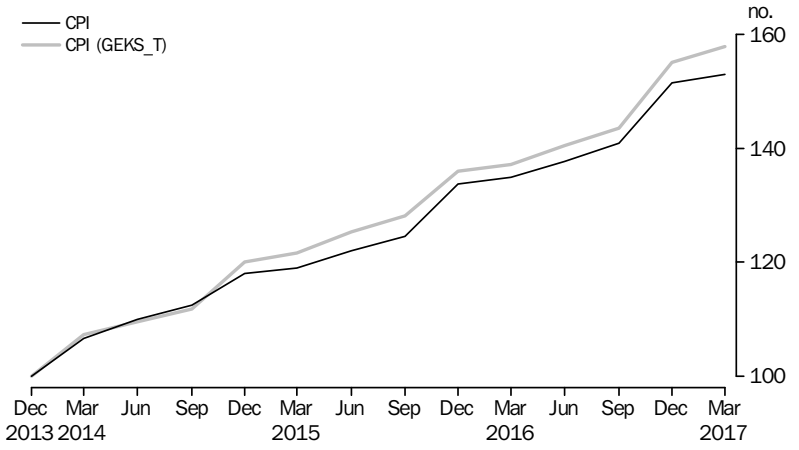
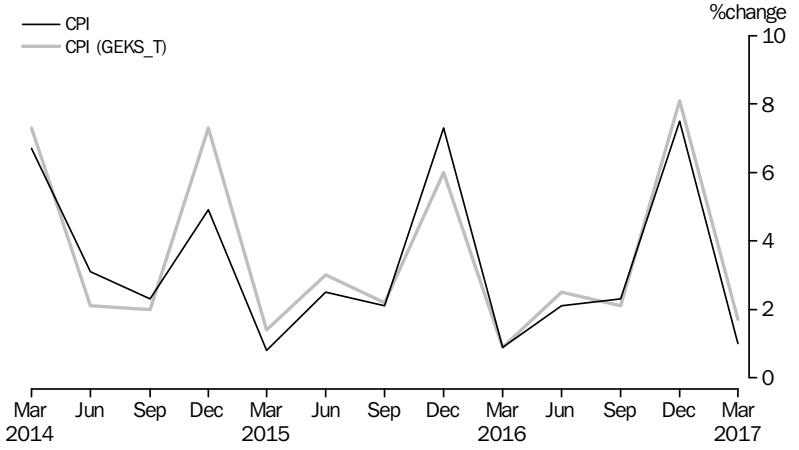


FIGURE 3.4: TOBACCO QUARTERLY PERCENTAGE CHANGE



3.4 The remaining figures plot similar comparisons for the Fruit and vegetables, Meat and seafood and Bread and cereal products sub-groups. The price indexes show the published CPI and CPI (GEKS-Törnqvist) follow similar price trends overtime. Across the different sub-groups, the quarterly percentage between the published CPI and CPI (GEKS-Törnqvist) is mixed, with the published CPI reporting higher/lower price change relative to the CPI (GEKS-Törnqvist) for certain quarters. In general, the quarterly percentage change reported by the CPI (GEKS-Törnqvist) is less volatile relative to the published CPI. This is particularly evident with the Fruit and vegetables sub-group results, with the CPI (GEKS-Törnqvist) accounting for consumer substitution in response to large price increases from fruit products. In contrast, the CPI assumes consumers purchase the same quantity of fruit each period irrespective of relative price change.

EMPIRICAL RESULTS

continued

FIGURE 3.5: FRUIT AND VEGETABLES PRICE INDEX

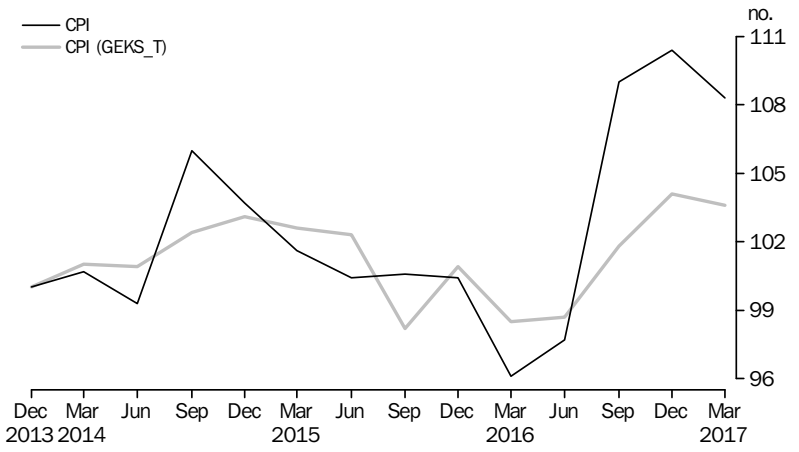


FIGURE 3.6: FRUIT AND VEGETABLES QUARTERLY PERCENTAGE CHANGE

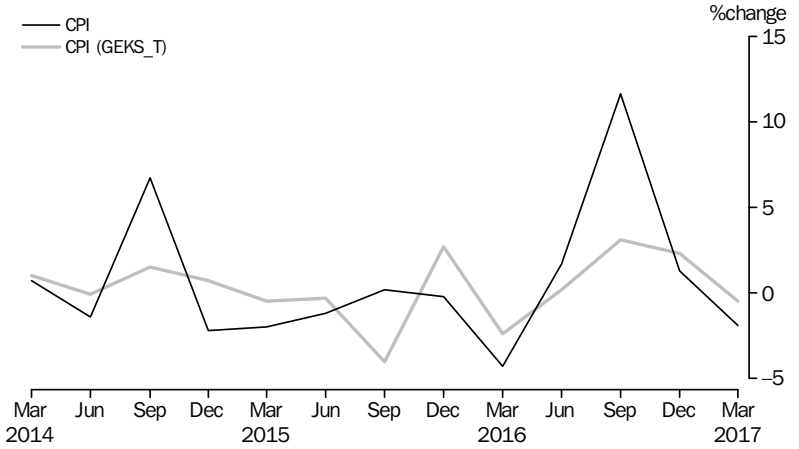
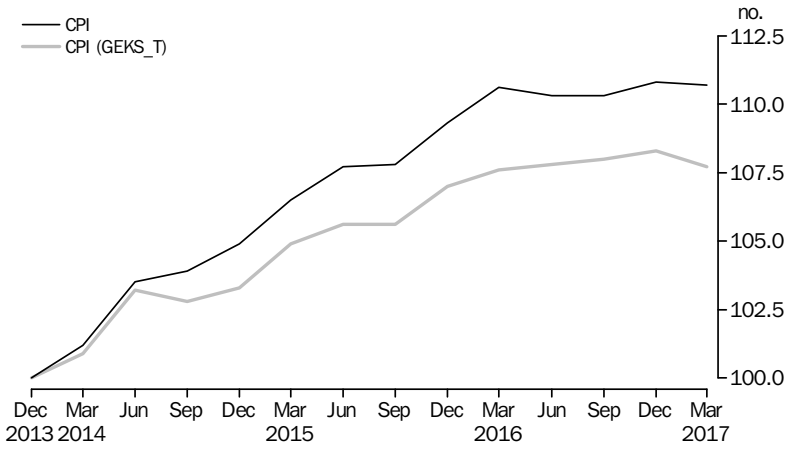


FIGURE 3.7: MEAT AND SEAFOOD PRICE INDEX



EMPIRICAL RESULTS

continued

FIGURE 3.8: MEAT AND SEAFOOD QUARTERLY PERCENTAGE CHANGE

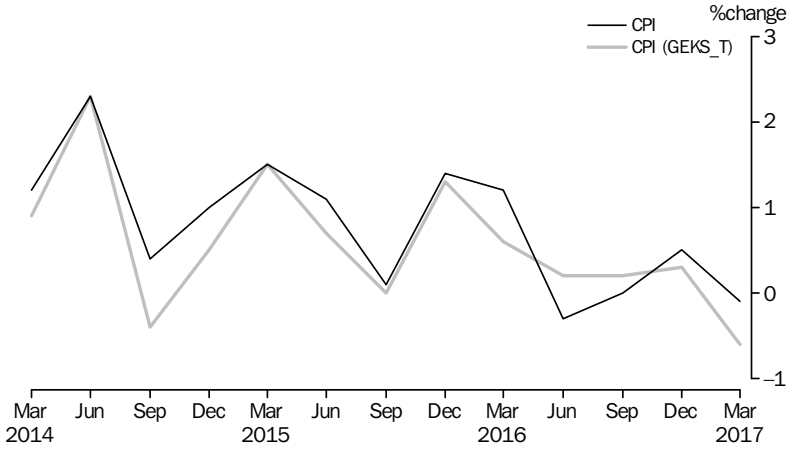
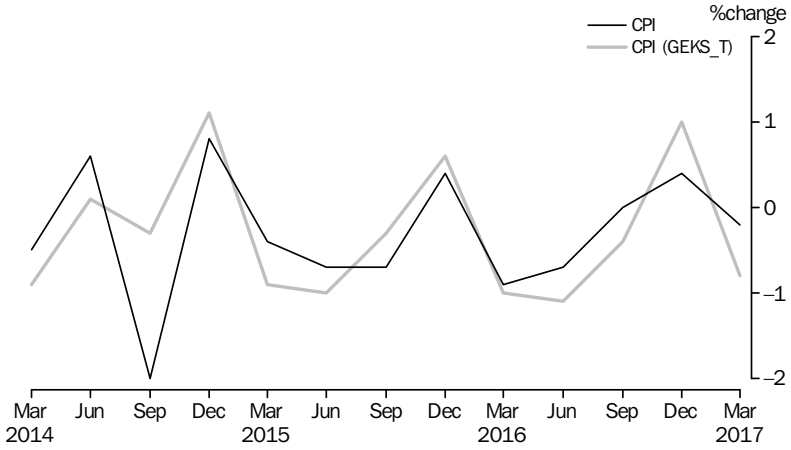


FIGURE 3.9: BREAD AND CEREAL PRODUCTS INDEX

FIGURE 3.10: BREAD AND CEREAL QUARTERLY PERCENTAGE CHANGE



CONSULTATION

4.1 The ABS has undertaken broad consultation regarding the implementation of multilateral methods to compile the Australian CPI. This commenced with the release of the Information paper: Making Greater Use of Transactions Data to compile the Consumer Price Index (cat. no. 6401.0.60.003), published 29 November 2016. Following this paper, the ABS sought user and stakeholder input to resolve the outstanding methodological challenges.

4.2 The ABS has collaborated with international experts and NSOs to resolve outstanding methodological issues (Appendix 1 and 2 contain peer reviews of ABS research). Additionally, the ABS conducted bilateral and multilateral consultations with key stakeholders, including: the Reserve Bank of Australia; the Treasury; Department of Social Services; Department of Finance; and State Treasuries. In all instances, experts, NSOs and stakeholders were supportive of maximising the use of transactions data to compile the CPI using multilateral methods.

4.3 This consultation with key stakeholders raised topics for further ABS research. These topics included:

(i) The choice of aggregating prices directly to the EC level using multilateral methods;

(ii) The choice and justification of multilateral methods; and

(iii) The choice and justification of the half splice extension method.

4.4 The ABS has conducted further research with the following conclusions:

(i) Aggregate prices using multilateral methods below the EC level using respondent classes as EAs.

(ii) Aggregate prices using the GEKS-Törnqvist multilateral method based on theoretical properties and empirical evidence; and

(iii) Aggregate prices using the mean splice extension method based on theoretical properties and empirical evidence.

4.5 In preparation for implementation in December quarter 2017, the ABS will parallel processes alongside the production of the CPI.

IMPLEMENTATION

5.1 The ABS will implement the methods proposed in this publication for 28 ECs in the Australian CPI (see paragraph 2.20). In summary, the methods specified for compiling price indexes from transactions data are:

- GEKS-Törnqvist as preferred multilateral method compiled using respondent classes as EAs.
- Weighted TPD run concurrently (for comparison purposes).
- Aggregate EAs together using Törnqvist index formula to form respondent indexes.
- Aggregate respondent indexes together using Lowe Index formula.
- Mean splice extension with a rolling window of 9 quarters

The following is a timetable for implementation:

- ABS to continue to monitor these methods during June quarter 2017 and September quarter 2017; and make refinements as required.
- ABS to implement new methods in December quarter 2017. This is to align the implementation of multilateral methods with the introduction of updated household expenditure data for weighting purposes[8].

8 See Information Paper: An Implementation Plan to Annually Re-weight the Australian CPI (cat. no. 6401.0.60.005)

CONCLUSION

6.1 The ABS is in an environment of transformation where new opportunities to access and interrogate 'big data' are becoming available to compile official statistics. One area the ABS has made significant progress is the use of transactions data to compile the CPI. Prices obtained from transactions datasets currently accounts for approximately 25 per cent of the CPI weight. The current methodology used for the implementation of transactions data replaced traditional (point-in-time) field collected prices with unit values in 2014.

6.2 While current methods used to compile the CPI represent a significant enhancement on traditional practices, opportunities exist to further enhance the methods used in the Australian CPI. To overcome the issues with traditional bilateral index formulae when using transactions data, academics and NSOs have reached consensus that multilateral methods are required to exploit the full amount of information provided in transactions datasets.

6.3 As part of the research program to Enhance the CPI, the ABS has conducted research on a selection of well-known matched-model multilateral methods for producing temporal indexes. Following further research and consultation with international experts, the ABS is now in a position to make a final decision on methods to be implemented into the Australian CPI. Section 5 of this publication details the specific methods the ABS plans to implement in December quarter 2017.

6.4 The implementation of these new methods would represent a significant enhancement to the Australian CPI. This includes using all the products available in the datasets (rather than a small sample of products) and weighting products by their economic importance (rather than using unweighted price indexes). In the medium term, the use of multilateral methods will require fewer resources to process and analyse price movements.

6.5 The historical analysis presented in this paper indicates this methodological change would have had a minor downward impact on the overall CPI. This may not translate into a similar result in future periods. At the sub-group level, empirical evidence provided in Section 3 showed similar price trends overtime with some short-term departures.

6.6 User and stakeholder input is welcome on the details of this publication. For further information relating to the implementation of new methods for transactions data, users should write to:

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APPENDIX 1 REVIEW BY PROFESSOR JAN DE HAAN

TRANSACTIONS DATA IN THE AUSTRALIAN CPI: RECOMMENDATION ON THE CHOICE OF MULTILATERAL METHOD AND EXTENSION METHOD

By Jan de Haan[9] 5 May 2017

SUMMARY

The ABS has decided to implement a multilateral price index method for the treatment of transactions data in the CPI. Based on theoretical arguments and empirical research conducted at the ABS and elsewhere, this paper recommends GEKS-Törnqvist as the main multilateral method, preferably applied at the elementary (i.e. lowest) aggregation level. Aggregating up the GEKS-Törnqvist price indexes at the elementary aggregation level to the expenditure class level should be done using the Törnqvist formula as fixing the weights may introduce upper level substitution bias. To extend the time series when new data becomes available, a "mean splice" with a 9 quarter window is recommended. The paper also suggests some further improvements, including the improved treatment of comparable items with different Stock Keeping Units.

ABOUT THE AUTHOR

Jan de Haan is a senior methodologist at Statistics Netherlands and a Professor at Delft University of Technology (currently on leave). He works primarily in the field of price index theory and practice. He is a member of the Steering Committee of the Ottawa Group on price indexes, a member of Statistics Canada's Prices Methodology Advisory Committee, and an elected member of the U.S. Conference on Research in Income and Wealth.

Over the last two decades, he conducted extensive research on the use of transactions data in the CPI and has been involved in the implementation of scanner data in the Dutch CPI.

He collaborated with the ABS in a number of ways, through visits, secondments and the 2006-2008 Australian Research Council Grant "Scanner Data in the Consumer Price Index: How to Expand and Improve Their Use", led by Prof. Kevin Fox (UNSW), with the ABS and Statistics Netherlands as industry partners. From February to December 2017 he is seconded to the ABS as a principal advisor.

BACKGROUND

The ABS has been using transactions data for several years to compile price indexes for the CPI. Essentially, the prices collected by visiting stores were replaced by unit values from transactions data. The methodology to construct price indexes at the Elementary Aggregation (EA) level, in particular the samples of items and the method to aggregate prices into price indexes, was left unchanged. Apart from cost benefits, the advantage is that unit values are the appropriate measures of prices actually paid by consumers.

Transactions data, also known as scanner data, provides the ABS with the opportunity to use a census of products and compile weighted rather than unweighted price indexes. This would further enhance the Australian CPI. Weighting by expenditure at the product level would be an important improvement. Transactions data also enables more accurate weighting of the price indexes at the EA level to form price indexes at the Expenditure Class (EC) level.

A distinct feature of transactions data is product turnover, which can be significant for some EAs. To maximize the number of matches in the data, chaining quarter-on-quarter price changes would seem useful. However, when sales occur, chain-linking weighted price indexes can lead to downward drift; see for example Ivancic (2007). Multilateral price index methods have been proposed to deal with this issue.

9 Division of Corporate Services, IT and Methodology, Statistics Netherlands and Delft University of Technology; email: j.dehaan@cbs.nl. The views expressed in this paper are those of the author and do not necessarily reflect the views of Statistics Netherlands.

BACKGROUND *continued*

The ABS decided to implement a multilateral price index method for the treatment of scanner data in the December quarter 2017. I strongly support their decision. This will lead to weighted price indexes, based on all the matched products available in the data sets, which are free of chain drift. Experiences at Statistics New Zealand and Statistics Netherlands, who already implemented multilateral price index methods, have shown that these methods perform as expected. There are also cost benefits since multilateral methods can be almost fully automated.

RECOMMENDATIONS

Several multilateral index number methods are available. The ABS previously excluded the Geary-Khamis method; the choice is between the GEKS and weighted Time Product Dummy (TPD) methods. The GEKS method transitivizes superlative bilateral indexes, such as Fisher or Törnqvist indexes. GEKS-Törnqvist has an advantage over GEKS-Fisher in that it facilitates decompositions. Weighted TPD is a regression-based method where the logarithm of price is regressed on time and product specific dummy variables in a multi-period context.

My recommendation is to use GEKS-Törnqvist as the main multilateral price index method. Where appropriate, or where the ABS previously identified issues with GEKS, TPD can be used instead. As a final check on their performance, I suggest running the two methods in parallel during the second half of 2017.

The ABS will construct multilateral price indexes for each data provider separately. The preferred level of aggregation for estimating multilateral indexes is the EA level. The EA-indexes should be aggregated to the EC level using the Törnqvist formula. At this stage, I would suggest aggregating the EC-indexes across data providers using annually fixed weights from scanner data.

The ABS has been investigating different methods to extend multilateral price index series when new data becomes available. I recommend the use of what is now known as a mean splice with a window length of 9 quarters.

JUSTIFICATION OF THE GEKS-TÖRNQVIST MULTILATERAL METHOD

The recommendation to use GEKS-Törnqvist as the main multilateral method is based on theoretical arguments, empirical evidence and practical issues, taking into account the environment of the ABS, such as key stakeholders' and academics' views.

Theory

The economic approach to index number theory suggests that, when comparing two periods (months or quarters), a superlative index number formula, such as the Fisher or Törnqvist, should be used. Superlative indexes treat the two periods in a symmetric fashion and account for substitution effects (ILO et al., 2004).

Item turnover in scanner data can be high, and to maximize the number of matches in the data, high frequency chaining is required. It turns out, however, that when sales occur in scanner data, some assumptions underlying the standard economic approach are no longer valid. In particular, the quantities of storable goods purchased after the sales period do not immediately return to their "normal" level, which produces drift in period-on-period chained superlative price indexes. The drift resulting from sales is typically downward.

The solution is to use a multilateral index method. A multilateral index is transitive, hence independent of the choice of base period and free from chain drift. The GEKS method is grounded in standard index number theory: it takes the geometric mean of all possible (matched-item) superlative price indexes across the estimation period, where each period serves as the base. In particular when item turnover is low, this method is best from a theoretical point of view. Ivancic, Diewert and Fox (2011) proposed the use of GEKS with a particular extension method (a movement splice) for the treatment of scanner data in the CPI [10].

10 They used GEKS-Fisher price indexes. In section 4 of the present paper, various extension methods are discussed. For rolling-year GEKS-Törnqvist indexes from Dutch scanner data, see de Haan and van der Grient

Theory continued

To fully account for substitution effects, implementing GEKS at the EC level would be preferable. On the other hand, there are good reasons to compile price indexes at the EA level; see below. Since superlative indexes are approximately consistent in aggregation, applying GEKS at the EA level will be fine, provided that the indexes are aggregated up to the EC level using a superlative index number formula. The use of Törnqvist bilateral price indexes in the GEKS procedure facilitates decomposition analysis. For reasons of consistency, the Törnqvist indexes at the EA level should preferably be aggregated up to the EC level using Törnqvist weighting.

When item turnover is relatively high, there may be some issues with GEKS. One of the reasons is that the "missing prices" for the new and disappearing items are not imputed; GEKS is a strictly matched-item approach. A model-based approach that imputes these prices might perform better, in particular when a hedonic model is used. The ABS does not systematically observe characteristics information, and so hedonic regression cannot be implemented on a large scale.

An alternative method is the regression-based weighted TPD method, which imputes the "missing prices" also. Krsinich (2016) proposed this method, in combination with another extension method (a window splice). Nevertheless, TPD is still a matched-item approach in that it utilizes longitudinal price information to estimate the parameters and therefore requires at least two observations for an item to be included. Consequently, new items will be introduced with a one period lag, similar to the GEKS method. It can be shown that the weighted TPD index is approximately equal to a standardized unit value index where the standardization factors - which can be interpreted as quality-adjustment factors - are based on the estimated item-specific parameters in the model. This raises two issues.

Firstly, and most importantly, after standardization, TPD is an approximately additive method. That is, the TPD method is appropriate for product categories consisting of items which, after standardization/quality adjustment, are perfectly substitutable[11]. Many ECs are too heterogeneous to apply the TPD method; standardization can only work for broadly comparable items. It is difficult to determine exactly when a product category consists of broadly comparable items, but some EAs may be sufficiently homogeneous to allow the use of a single TPD model.

Secondly, because information on item characteristics is not used, there is no guarantee that the standardization factors are good approximations to the true quality-adjustment factors (de Haan, Hendriks and Scholz, 2016).

Empirical evidence

The ABS has been conducting extensive empirical research on multilateral price index methods (ABS, 2016). The empirical evidence is not conclusive, however. Surprisingly, the evidence does in general not point to upward bias in weighted TPD indexes at the EC level as the economic approach to index number theory predicts. It is not entirely clear why this is the case. One reason could be that standard theory assumes a fixed universe of items, i.e. no item turnover, whereas real data is typically characterized by significant churn. However, even for product categories, both at the EA and EC level, with limited item turnover, the ABS did not find systematic differences between GEKS and TDP indexes. Similar findings were reported by Statistics Netherlands on scanner data from supermarkets and department stores (Chessa, 2016).

(2011).

11 Diewert and Fox (2017) showed that TPD is also consistent with an elasticity of substitution equal to one. This result holds prior to standardization, but it is a bit unclear what the impact of standardization on their finding is.

Empirical evidence continued

Unpublished work by the ABS showed that the GEKS-Törnqvist index can be written in a form which is mathematically very similar to the weighted TPD index. In addition, de Haan (2015) showed that the weighted TPD index can be interpreted as an imputation Törnqvist-type price index. These results provide some insight as to why the differences between the two methods may be small, but more work remains to be done to come up with a completely convincing answer.

In any case, it is reassuring that GEKS and weighted TPD often lead to similar price trends; in practice the choice of multilateral method appears to be less important than economic theory suggests.

Current practices and the environment

As was mentioned above, there are several reasons to prefer calculating GEKS indexes at the EA rather than EC level, data permitting. First, this leaves the current structure of the CPI more or less unchanged, which may be useful when explaining new methods to users as well as practitioners. Second, stratification of an EC into EAs provides some flexibility. For example, when an unexpected problem occurs in an EA, the remaining EAs would not be affected. Third, it enables the ABS to use different methods - GEKS-Törnqvist or weighted TPD - for different EAs belonging to the same EC, if deemed necessary.

In their comments on the ABS Information Paper (ABS, 2016), the Reserve Bank of Australia stressed the importance of the economic approach to index number theory when choosing a multilateral method. In other words, they prefer GEKS over weighted TPD. Diewert and Fox (2017) recently recommended the GEKS-Törnqvist method for the treatment of scanner data[12].

JUSTIFICATION OF THE MEAN SPLICE EXTENSION METHOD

When new data becomes available, previously estimated multilateral indexes change, which is problematic because the CPI cannot be (continuously) revised. A number of methods are available to extend a multilateral time series without revising the published price index numbers. We distinguish between rolling window methods and an annually-chained direct method.

Rolling window methods estimate multilateral price indexes on a window with fixed length, say T quarters (for the quarterly Australian CPI), which is shifted forwards each quarter. The results of the latest window are then spliced onto the existing time series. For example, the most recently estimated quarter-on-quarter GEKS index movement can be spliced onto the index level of the previous quarter. This "movement splice" was used by Ivancic, Diewert and Fox (2011). Another option is to splice the most recently estimated movement across the whole window onto the index level of T-1 quarters ago. Krsinich (2016) proposed this "window splice". These are extreme choices, and de Haan (2015a) proposed a "half splice", where the most recently estimated second half of the index movement is spliced onto the index level of (T-1)/2 quarters ago (assuming T is an odd number).

The above extension methods splice price movements onto a single link quarter. With a volatile price series, as we often observe in scanner data, different link quarters yield different results. Moreover, there are more possible index movements and link quarters than the three mentioned above. As all link quarters are equally valid, Diewert and Fox (2017) proposed a "mean splice"[13] by taking the geometric mean of all the price indexes that are obtained by using every possible link quarter, given the window length. This method makes the result independent on the choice of link period, which is a useful property.

12 Note that they refer to GEKS-Törnqvist as CCDI.

13 Ivancic, Diewert and Fox (2011) already alluded to the use of a mean splice.

JUSTIFICATION OF THE MEAN SPLICE EXTENSION METHOD *continued*

The ABS previously identified some issues with movement and window splicing; the movement splice can yield downward drift due to disappearing items with unusually low prices (clearance sales) whereas the window splice can yield downward drift due to new items entering with unusually high prices. Recent decomposition analysis at the ABS indicated that the mean splice acts more like a movement splice near the start of the window (thus mitigating problems with disappearing items) and more like a window splice near the end (mitigating problems with new items). Further empirical exercises showed that the mean splice indeed works as expected, further strengthening the case for using it.

The choice of length of the estimation window is largely an empirical matter. Ivancic, Diewert and Fox (2011) argued that it should be at least 5 quarters (or 13 months) to be able to include strongly seasonal goods. Since seasonal patterns may shift slightly over time, it would be safer to choose a somewhat longer window. On the other hand, the window should not be too long because this will incur a loss of characteristicity: past prices and price changes will disproportionally affect the estimated price movements for recent periods[14]. Empirical research at the ABS revealed that, at least for many products sold in supermarkets, the trend in rolling window GEKS indexes becomes flatter when increasing the window length. All in all, I recommend a window length of 9 quarters (or 25 months).

Chessa (2016) proposed an annually chained direct extension method, in part to comply with recommendations for the European Union Harmonized Index of Consumer Prices. For quarterly data, the idea is to construct short-term multilateral index series, starting in the December quarter and ending in December of the next year, i.e. with a length of 5 quarters, and chain link them in the December quarter of each year to obtain a long-term time series[15]. The length of the estimation window for the short-term indexes is extended each month, without publishing the revised index numbers - the index for the March quarter in the short-term series is estimated on two quarters of data (a bilateral rather than multilateral comparison), and so forth, until in the December quarter five quarters of data is used.

A potential drawback of Chessa's (2016) proposal is that the price indexes for the first quarters of each year are based on sparse data and expected to be quite volatile. This was confirmed by empirical research at the ABS. Also, the December quarter acts as the short-term index reference period and is thus given special importance. If, for some reason, the December quarter is "unusual", the results may be adversely affected. So, although annual chaining can be useful because this will probably not lead to drift, I would not recommend Chessa's (2016) extension method[16].

POTENTIAL IMPROVEMENTS

To keep the production system relatively simple, I suggest using annually fixed weights from the scanner data to aggregate the EC GEKS price indexes across the different data providers. Annual updating the weights alleviates potential chain substitution bias. In the future, the ABS could decide to change over to Törnqvist weighting, but I do not consider this a priority.

14 In terms of the TPD method, a long window means that the item-specific parameters are constrained to be fixed over time for a longer period, and this is generally not good practice. Note that a rolling window approach would continually update the estimated parameters. De Haan (2015b) discussed the choice of splicing method for rolling year TPD and time dummy hedonic indexes.

15 Chessa (2016) used the Geary-Khamis multilateral method in combination with defining items by their characteristics.

16 Rolling window approaches can introduce some drift again because it impairs the transitivity property of multilateral price indexes. Lamboray (2017) suggested to combine Chessa's (2016) annually chained direct method with a rolling window approach.

POTENTIAL IMPROVEMENTS *continued*

An important aspect when constructing matched-items (multilateral) price indexes is the choice of item identifier. Items in scanner data are typically identified by barcode. Some products with different barcodes, however, are similar from the consumers' point of view. Also, barcodes often change if unimportant characteristics change, such as type of packaging. In that case, matching at the barcode level overestimates item churn, and disguised price changes due to re-launches of comparable items with different barcodes will not be observed; see also Dalén (2017). Such disguised price changes are typically upward, and missing them produces downward bias in the index.

Fortunately, the ABS receives Stock Keeping Units (SKU) from the data providers and calculates unit values across SKUs rather than individual barcodes. This mitigates the above issues. In some instances, for example for the Personal Care EC, even SKU may be too detailed so that matched-item methods, including GEKS, can yield biased results. Characteristics information extracted from item descriptions in the scanner data sets could potentially be used to identify items from their characteristics rather than SKU and apply a multilateral method to these broadly defined items, which is the approach followed by Statistics Netherlands (Chessa, 2016), or to estimate hedonic multilateral price indexes, for example as described by de Haan and Krsinich (2014) (2017).

As mentioned before, the ABS is currently not extracting characteristics information on a large scale, and it may therefore be sensible to exclude EAs or ECs for the time being where this problem occurs and continue with the current unweighted, sample based geometric means index.

The ABS previously identified another issue with GEKS: the GEKS index seems to be more sensitive to tiny quantities than weighted TPD, for example when clearance sales occur. Increased volatility of the results is not such a big issue - price indexes from scanner data are often volatile anyway - but bias obviously is. Perhaps the modification of GEKS proposed by Lamboray and Krsinich (2015) could help resolve the clearance sales issue. Another possibility would be to use some form of filtering. The drawback of these approaches is their ad hoc and sometimes arbitrary nature.

Another potential issue with GEKS is the loss of characteristicity within the estimation window, say the recommended 9 quarters. A weighted GEKS approach, for proposed by Melser (2016), could be considered to reduce the loss of characteristicity. The bilateral indexes are down-weighted the further away the link period is from the most recent period. The aggregate matched-items expenditure shares seem to be a useful choice for the weights.

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COMMENT ON "MAKING GREATER USE OF TRANSACTIONS DATA TO COMPILE THE CONSUMER PRICE INDEX, AUSTRALIA", AUSTRALIAN BUREAU OF STATISTICS 6401.0.60.003, RELEASED: 29 NOVEMBER 2016

By Kevin J. Fox [17] 20 April 2017

SUMMARY

This comment assesses the plans of the ABS for expanding the use of transactions data in CPI construction. The focus is on two issues that were noted in ABS (2016) as being unresolved: (i) the best multilateral index number method to use, and (ii) the best way of extending the resulting series when new observations become available. Drawing on research conducted since the publication appeared, recommendations are made regarding both issues. Specifically:

1. It is recommended that the CCDI (or "GEKS-Törnqvist") multilateral index be used.
2. It is recommended that the "mean splice" be used as the extension method.

Using transactions data with multilateral methods to construct the CPI is an improvement over current practice. Internationally, there is much interest in moving to such methods. Since the 1990s, the ABS has been a leader in research on this topic, engaging with academics and researchers from other NSOs. Now, as other NSOs begin to implement new methods for using transactions data in their CPIs, Australia should not be left behind, as deviating from international best practice would bring the credibility of the Australian CPI into question.

Besides the benefits from using more information in a more efficient way, there are additional benefits that can arise from the proposed changes. These include the potential for improving the timeliness of CPI releases and the potential to move resources from data collection and processing to analytics, which can better inform policy formulation.

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He has had a long association with the ABS, being a member of the ABS Methodology Advisory Committee since 1999. He chaired the ABS Advisory Group for the 16th Series CPI Review, 2009-2010, and is a member of the Productivity Measurement Reference Group and the Input-Output User Group.

He has conducted research on the use of transactions data in the CPI, much of it stemming from collaborations with the ABS, including the following:

2003-2005 Australian Research Council Linkage Grant, for "Can Electronic Point-of-Sale (POS) Data Improve the Australian Consumer Price Index?" with R.J. Hill. Industry Partner: Australian Bureau of Statistics.

2006-2008 Australian Research Council Linkage Grant, for "Scanner Data in the Consumer Price Index: How to expand and improve their use," with J. de Haan, P-H. van Mulligan and M. Silver. Industry Partners: Australian Bureau of Statistics and the Central Bureau of Statistics (Netherlands).

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1. THE USE OF TRANSACTIONS DATA IN THE CPI

The availability of transactions level data in large quantities provides huge advantages for National Statistical Offices (NSOs). The recent ABS publication (ABS 2016), henceforth referred to as "the report" convincingly sets out many of the advantages of using such Big Data, so they will not be repeated here. A point worth emphasising, however, is that there is nothing sacred about current CPI construction methodology.

Existing methods, while differing somewhat across countries, are largely based on price information sourced from sampled prices (e.g. from sending price collectors to record prices listed on supermarket shelves). These prices are combined with importance weights for the different product categories, where the weights are sourced from periodic expenditure surveys. Clearly there are potential problems, for example if the sampled prices are not representative of actual consumer purchases (e.g. no one buys the goods at those listed prices) or the importance weights are out of date due to infrequent surveys. In addition, these weights are usually only available at expenditure class levels rather than at the level of individual goods, requiring the use of average prices (across goods, outlets and time). With information available on all goods prices and the quantities purchased at these prices, this is not how one would design a price index. Rather, current CPI construction has developed as a response to historically limited data availability.

The advent of readily available transaction level data then allows for an overhaul of traditional methodology, as the data constraint has been enormously relaxed. However, this opportunity for improved price index construction has been somewhat offset by the complexities involved in the use of high-frequency data. One of these has been the observation that traditional bilateral index number theory can break down when using such data.

The response by NSOs to date has been to make limited use of transactions data, such as to directly replace some price sampling, but not making direct use of the available quantity information. The ABS report (p. 1, 1.3) indicates that from March 2014 there was a significant increase in the use of transactions data, "now accounting for approximately 25% of the weight of the Australian CPI". This can be thought of as using a more comprehensive data source in combination with traditional CPI compilation methodology. This is an improvement (more price information means a more representative price for each product), but is still far from making optimal use of the available information.

Drawing on recent developments in the academic literature, starting with Ivancic, Diewert and Fox (2009, 2011), some NSOs have started to use multilateral index numbers in CPI construction when using transaction level data, but in a very limited fashion; see Krsinich (2015) and Chessa (2016). Multilateral methods are drawn from the international comparisons literature, and provide a solution to the chain drift problem when applied in the time series context. This problem can be severe when constructing price indices with transactions data, even when using superlative index formulae as recommended in the ILO (2004) CPI Manual; see Ivancic, Diewert and Fox (2011) and de Haan and van der Grient (2011).

Some complexities also arise in the use of such methods. First, a choice of multilateral index number formula needs to be made. In traditional CPI construction, the choice of formula is typically constrained by data availability, especially the availability of expenditure weights, leading to the use of the (non-superlative) Lowe index; see ABS (2011, p. 23, 4.38).

Second, as the CPI is non-revisable, a way of extending the price index as new information becomes available is required. The issue is the following. In international comparisons, multilateral methods are applied over a set of countries to make comparisons of relative prices or output. The addition of another country to this set of

1. THE USE OF TRANSACTIONS DATA IN THE CPI *continued*

comparisons can change some or all relativities, as its addition contributes further information. In the time series context, multilateral methods are applied over an initial time period, or "window", and as data for a new period becomes available, simply extending the window by the additional period would mean that earlier estimates may be changed. This is unacceptable for a series which should not be revised, such as the CPI. Hence, a method that respects this constraint is needed for extending the original window as data for more periods become available.

The report assesses, theoretically and empirically, the use of alternative multilateral methods and extension methods. It also addresses practical issues of implementation, specifically around the level of aggregation at which these methods are applied.

To put the report in context, it is worth noting that it is the latest in a long series of research on transactions data by, and supported by, the ABS over almost twenty years. Much of this has been in collaboration with academics and experts from other NSOs[18]. The approach of the ABS has thus been to demonstrate appropriate caution when considering new data sources and methods, while collaborating broadly to explore opportunities that can provide significant benefits. In taking this approach, in my view the ABS has provided an exemplar for productive government engagement with external experts.

In what follows, this comment will provide an overall assessment of the report, make some specific comments, and provide recommendations. The focus is on two issues that were noted in the report as being unresolved: (i) the best multilateral index number method to use, and (ii) the best way of extending the resulting series when new observations become available.

2. OVERALL ASSESSMENT AND SPECIFIC COMMENTS

1. The ABS Data Quality Framework (DQF) is central to considerations, along with the relevant academic literature and research conducted by other NSOs. This is all very satisfactory.

2. The reported empirical results using actual transactions data enhances our understanding of the relative performance of the methods. The amount of work and care that has gone into these empirical assessments is impressive.

3. The descriptions of the background issues in Section 1, the multilateral methods in Section 2, and the extension methods in Section 3, are accurate and informative.

4. In Section 4, the use of the "test approach" to assess the performance of the alternative multilateral methods is appropriate and presented in a thoughtful and informative manner. In particular, the report does not simply present a mechanical application of received results, but assesses the relevance of tests for the context faced by NSOs. It is impressive that new results are derived and presented in Appendix 2.

5. 4.23, page 18: "To the best of our knowledge, the TPD and QAUV_TPD methods have not yet been assessed rigorously from this economic approach." Diewert and Fox (2017) have now assessed the TPD from this perspective, and show that it is an approximately additive method that is consistent with linear (perfect, or infinite, substitutability) and Cobb-Douglas (elasticity of substitution equal to one) utility functions. Clearly the first case is unrealistic in general, while the second case may approximate actual preferences in some cases. The QAUV_TPD method will share the same substitution possibilities as the GK method (discussed in the following point), as the only difference is in how the quality adjustment factors are estimated.

18 See e.g. Jain and Abello (1999, 2001), Jain and Caddy (2001) and Moore (2014). The idea of using transactions data with multilateral methods came out of research supported through two Australian Research Council Linkage Grants with UNSW researchers, the second of which also involved Statistics Netherlands. Research experience and results shared at the annual UNSW Economic Measurement Group Workshop, supported by the Linkage grants, also significantly advanced understanding and informed practice.

2. OVERALL ASSESSMENT AND SPECIFIC COMMENTS *continued*

6. 4.24, page 18: "In contrast, the GK and other additive methods are consistent only with linear utility functions." The GK method is also consistent with Leontief (perfect nonsubstitutability) as well as linear (perfect substitutability) utility functions; see Diewert (1999, p. 28). Clearly neither case is realistic, and hence unlikely to appropriately represent actual consumer preferences.

7. 4.24, page 18: The test used for assessing substitution bias in the multilateral indexes is limited by not knowing the actual substitution elasticities. The approach of Diewert and Fox (2017), partly in response to this work, is to generate artificial data under specific assumptions on the elasticity of substitution. This then allows an assessment of the performance of methods when the true elasticity that generated the data is known. For elasticities in a range regarded as being reasonable (based on empirical evidence), the GK and TPD methods were found to perform quite poorly. In any empirical application, it could be found that these methods approximate each other and the results from methods with better substitution modelling properties. However, this is not an argument for choosing these methods as the default ex ante. Fortuitous empirical correspondence of theoretically poor methods with theoretically better methods is not a basis on which to justify the use of the theoretically poor methods. Diewert and Fox (2017) find in favour of the CCDI multilateral method, call the GEKS method in the report and in much of the literature[19].

8. 4.31, page 19, Interpretability: It is noted that the CCDI/GEKS approach is perhaps the easiest to grasp, as price movements are derived by combining superlative bilateral index numbers. There is an additional property of the CCDI index which facilitates interpretability. It is based on the use of the Törnqvist bilateral index, which is a share weighted geometric mean of price ratios. Following the results of Caves, Christensen and Diewert (1982) and Inklaar and Diewert (2016), Diewert and Fox (2017) note that the CCDI method can be interpreted as comparing the level of prices in each period with the corresponding level of prices in an average observation. This provides a significant interpretability advantage over other methods, including the Fisher-index-based GEKS method.

9. 4.36 and 4.37, page 20: The simple multiplicative decomposition property of the bilateral Törnqvist index (having a weighted geometric mean form) is inherited by the CCDI multilateral index. This is appropriately noted as an attractive property, and provides an additional advantage of using the CCDI method.

10. Summary of Section 4: In terms of the Test Approach to assessing multilateral methods, there is no clear winner. In terms of the Economic Approach, following the recent results of Diewert and Fox (2017), the arguments in favour of the CCDI method are somewhat stronger than in the report. In terms of Flexibility, the CCDI method is again found to be amongst the preferred methods. In terms of Interpretability, the CCDI method has advantages in addition to what is noted in the report (see point 8 above). Hence, based on the considered criteria and complemented by the results of Diewert and Fox (2017), it appears that there are strong arguments in favour of using the CCDI method.

19 The bilateral index formula used in the standard GEKS multilateral method is the Fisher Ideal index. Sometimes it is replaced by the Törnqvist bilateral price index formula. As Fisher and Törnqvist indexes often approximate each other closely in empirical applications, it is not uncommon for the resulting multilateral indexes to be both called "GEKS", as in the report. De Haan and van der Grient (2011; 41) called the Törnqvist based multilateral indexes GEKS-Törnqvist indexes. Feenstra, Ma and Rao (2009; 171-172) also noted that Törnqvist bilateral price indexes could be used in place of Fisher price indexes in the GEKS methodology. Fox and Syed (2016; 401) call the Törnqvist-based indexes CCD indexes. Caves, Christensen and Diewert (1982) (CCD) used the GEKS methodology in the quantity context, using bilateral Törnqvist quantity indexes as their basic bilateral index formula. Inklaar and Diewert (2016; 429) extended the CCD methodology to making price comparisons across production units. Hence, to distinguish the Fisher- and Törnqvist-based indexes, and to reflect the contributions of CCD and Inklaar and Diewert, Diewert and Fox (2017) called the Törnqvist-based multilateral indexes as CCDI indexes, and reserved GEKS for the traditional Fisher-based indexes.

2. OVERALL ASSESSMENT AND SPECIFIC COMMENTS *continued*

11. 5.3, page 22: The data constraints that led to the traditional CPI compilation methods are very nicely explained. The emergence of current practice as a response to data constraints is a point worth emphasising in proposing to change practice now that the data constraint has been significantly relaxed.

12. 5.5, page 22: The proposed structure, illustrated in Figure 5.1 for aggregation seems sensible. Moving away from traditional unweighted elementary aggregates is an appropriate response, and the reasons provided (both practical and theoretical) are very sensible. Practical reasons (motivated by the nature of the data received by the ABS from providers) aside, being able to better account for substitution across a wider range of items is attractive.

13. 5.10, page 25: The empirical deviations of the CCDI ("GEKS") method from the other multilateral methods is interesting. As noted above, the relative properties of the CCDI method and the evidence of Diewert and Fox (2017) suggest that it should do well in approximating the truth. The "truth" is hard to assess in any uncontrolled empirical application, so it is hard to determine how these deviations should be interpreted. This suggests that, while the CCDI method is ex ante to be preferred, it would be worthwhile running another multilateral method in parallel to identify any method specific differences. The use of the regression based (weighted) TDP method seems sensible, as it allows more reasonable substitution possibilities compared to the GK and QAUV_TPD methods, and being regression based it can provide measures of statistical significance for the estimated coefficients.

14. 5.14, page 28: The results presented in figures 5.8-5.11, for the example of Snacks and Confectionery, are very interesting. Multilateral methods, having the property of being "transitive", will not be subject to chain drift bias, hence the proposal for their use. However, extending the series may introduce chain drift bias, and the extent of this bias may depend on the extension method chosen. These figures provide evidence on this, and show that there can be significant downward bias introduced by the extension methods. In the presented examples, the "half splice" performs relatively well (closest to the corresponding multilateral method applied to the full data period). The "direct extension" method of Chessa (2016) seems hard to justify (especially the varying window length), and unsurprisingly it is shown that it can perform very badly, i.e. it can introduce significant chain drift. It seems that for both theoretical and now empirical reasons, this can be excluded from further consideration. The relatively good performance of the "half splice" may be a result of the particular data examined. The difference between the "window splice", "half splice" and the "movement splice" methods is the choice of linking period between the old and new windows (first period of the new window, a middle period, and last period of the old window, respectively).

A problem with the approach used to assess these methods is the following. The benchmark for each multilateral method is the method applied over the full 58 time periods. As noted in 1.19 (page 4), with the use of multilateral methods there is a tension between transitivity and "characteristicity"; as multilateral methods use data from periods other than those being directly compared, there can be a loss of relevance of the index, i.e. if the comparison between two periods is affected by data from periods with limited relevance. As the window length becomes longer, data from more chronologically remote periods influence all bilateral comparisons to some extent. Hence, the benchmark indexes used in figures 5.8-5.11 may be suffering from a serious loss of characteristicity due to the long window length. The problem with using this approach to find a definitive answer on the best extension method can be thought of as one of not knowing the truth.

2. OVERALL ASSESSMENT AND SPECIFIC COMMENTS *continued*

Diewert and Fox (2017) therefore used a different approach to assess the methods[20]. By using their artificial data generated assuming various elasticities of substitution, they know the truth. They concluded that rather than choosing one period for linking the old window with the new window, where the resulting index could depend significantly on that choice of period, a geometric mean approach could be used. That is, using an average of the resulting price level for the new period from using all overlapping periods for the linking in turn. This has the advantage of treating all overlapping periods symmetrically, which as an ex ante default principal can be argued to be reasonable[21], and the approach can moderate the influence on the resulting index of a linking period or periods with unrepresentative data patterns.

3. SUMMARY AND CONCLUDING COMMENTS

This is an excellent and timely piece of work by the ABS. It continues their research dating back almost twenty years on the potential for transactions data for improving the CPI. It is thoughtful in its structure, systematic in its approach and it provides insightful new evidence on the behaviour of methods of interest.

A convincing case is made for the desirability of expanding the use of transactions data in the CPI, something which is now very possible due to the work over many years done by the ABS, both internally and through collaborations. Other NSOs have recently started to make changes to CPI construction in light of this work, and more are likely to follow. To maintain the credibility of the Australian CPI, it would be timely for the ABS to also move to implementation.

A goal of no field collections seems feasible and desirable. This will allow a reallocation of resources from collection and processing to automation and analytics. It can also facilitate the production of a monthly CPI, a key recommendation of the last major review of the CPI; see ABS (2010). Potential improved accuracy issues aside, additional analytics and improved timeliness can better inform policy formulation.

The report identifies two unresolved issues for the broader use of transactions data in the CPI: (i) the best multilateral index number method to use, and (ii) the best extension method to use.

The paper which originally proposed multilateral methods in this context - Ivancic, Diewert and Fox (2009, 2011) - proposed either the GEKS method or the TPD method (both gave similar results in their empirical work). It was combined with what has now become known as the "movement splice" for extending the CPI series when a new period's data became available. Different multilateral methods and extension methods have subsequently been suggested and applied in this context. The report reviews and assesses these alternatives, and provides empirical evidence on their use. This is illustrative of broader ABS experimentation on these methods using data on a diverse range of product classes at different levels of aggregation.

This is all very informative. It also represents ample caution in relation to understanding the impact of changes in CPI data sources and construction methodology, as well as significant in-house expertise in analysing these issues.

20 This method was initially suggested by Ivancic, Diewert and Fox (2011, footnote 19, page 33).

21 In any particular set of data, there may be circumstances where one or more periods are excluded from consideration as linking points, depending on the characteristics of the data or exogenous expert knowledge. This implies a zero or one weighting scheme in forming a geometric average in obtaining the index value for the new period. Using a more general weighted mean approach is also possible, but introduces an extra level of complexity in determining the appropriate weights. There does not appear to be sufficient evidence at this stage to support a weighted mean approach, but it is a topic worthy of research.

3. SUMMARY AND CONCLUDING COMMENTS *continued*

Recent work by Diewert and Fox (2017), stimulated in part by the ABS report, recommended the following in regards to the two unresolved issues noted above:

1. Recommended multilateral method: CCDI (or "GEKS-Törnqvist") multilateral index.
2. Recommended extension method: The "mean splice".

As with current CPI methodology, there is always the possibility for future research to reveal means for enhancing the methods used[22]. At this time, however, implementation of the Diewert-Fox recommendations in points 1 and 2 above seem not only feasible but desirable, especially relative to the limitations imposed by data constraints on current CPI construction methodology.

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22 Diewert and Fox (2017) also note some promising research directions.

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