Data Sources for CPPIs: An Overview and Strategy.

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Abstract

Commercial property price indices (CPPIs) should be based on market transaction prices. Yet in monitoring average price changes over time price data can be sparse and the properties transacted each period of a different quality-mix. Due to the heterogeneity of commercial property, CPPI measurement requires a quality-mix adjustment so that the prices of like properties are compared over time with like. An appealing way around this sparse data and quality-mix adjustment problem is to use price data on broadly the same properties over time and avoid transaction price data. Tax or investment appraisal data or market valuations of real estate investment trusts (REITs) are two commonly used alternatives. While convenient, both such series can seriously mislead macroprudential and macroeconomic-policy makers. In this overview paper we point to the deficiencies of these data sources, outline and argue for the use of hedonic methods of quality-mix adjustment that are designed to work with sparse transaction price data in thin heterogeneous commercial property markets.

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I. Introduction

Commercial property price indexes (CPPIs) are hard to measure. Commercial property comes in many types including: hotels; offices; wholesale and retail outlets; and buildings for traffic and communications, industry and warehouses, public entertainment, education, hospitals, and institutional care. There is much diversity within each type, for example, shops vary in size (small traders to large hypermarkets/department stores), location (prime downtown to local), type of location (shopping malls, high-streets, local stores) and much more.[2] This heterogeneity of commercial property makes the measurement of CPPIs problematic. Average prices of retail property, for example, may increase over time but this may in part be due to a change in the quality-mix of the properties transacted. For example, more larger stores in better (more expensive) locations sold in the current quarter compared with the previous quarter would bias upwards a meaningful measure of the change in average property prices. There is a need to measure constant-quality property price changes and avoid this problem of changes in the quality-mix of properties transacted polluting the measurement of price change.

A second problem is the infrequent turnover of commercial properties, especially for industrial properties. A market price can only be identified when the property is transacted leading to a sparseness of price observations—thin markets. Infrequent transactions for heterogeneous properties is the perfect storm for CPPI measurement.

The seemingly appealing way around this sparse data and quality-mix adjustment problem is to use price data on broadly the same properties over time and avoid transaction price data. Tax or investment appraisal data or market valuations of real estate investment trusts (REITs) are commonly used alternatives to transaction data. Appraisal data and REITs have the attractive property of including regularly-surveyed assessed prices of properties providing a matched/paired panel database of property price estimates. Appraisals can in principle be undertaken on all properties irrespective of whether they are transacted thus giving at least the appearance of not suffering from the problem of sparse data. The matching of prices of the same property further enables price indexes to be aggregated without an undue concern about changes in the quality-mix of properties transacted.

However, while indexes based on appraisal prices seem promising, appraisals are often only undertaken annually, have a subjective element and possible bias, and been found to lag and overly smooth corresponding transaction indexes. While convenient, such series can seriously mislead macroprudential and macroeconomic-policy makers. In this overview paper we point to the deficiencies of these data sources, outline and argue for the use of hedonic methods of quality-mix adjustment that are designed to work with sparse transaction price data in thin heterogeneous commercial property markets.

Problems of infrequent transactions on heterogeneous properties also arise with residential property price indexes (RPPIs) but these problems are not so severe and have been largely overcome due to developments in data availability and measurement methodology. The Bank of International Settlements (BIS) maintains a database of RPPIs for 60 countries and CPPIs for 16 countries, the coverage and periodicity of the CPPI series varies from country-to country.[3]

[2] Commercial property can be broadly defined to include all property other than owner-occupied housing and property used in non-market activities (social housing and, for example, most types of non-residential property owned by government). "Types" of commercial property are taken from the *Classification of Types of Constructions* (United Nations/Eurostat, 1998): a nomenclature for the classification of constructions according to their type (Jens Mehrhoff in Eurostat (2017, page 32) and Mehrhoff (2017).

[3] The BIS Property Price database is available at: https://www.bis.org/statistics/pp_detailed.htm. The CPPIs are limited for two countries (Philippines and Korea) to the price of land only, for two further countries to annual series (Poland and Portugal) and for one country to a bi-annual series (Greece).

Section II critically examines these alternative data sources used for CPPIs and outlines some valuable research that takes hedonic CPPIs and compares the results with appraisal- and REIT-based indexes finding empirical evidence that indexes compiled from the latter data sources unduly smooth and, for appraisal indexes, can considerably lag hedonic transaction-based CPPIs.

Section III briefly outlines some basic sampling theory to help support the case for using the recommended RPPI practice of a transaction-based hedonic approach (Hill et al., 2018). We argue, on the basis of the sampling theory, that the right course of action where sub-property markets have too few transactions is not to turn to appraisals or REITs, but to identify the underlying data as being too sparse to provide macro-economists with reliable RPPIs due to the overly wide confidence intervals accompanying the estimated CPPI measure.

Section IV recognizes the problem of sparseness of data for the hedonic methodology and points to methods that have been developed to better adapt the hedonic-transaction methodology to thin commercial property markets.

Section V points to the political economy of international organizations wanting to respond to the demands for data as likely to mislead users formulating macro-economic policy and financial stability. The honest and professional stance is to focus on markets segments, such as offices and retail, where sample sizes are sufficiently large and there is not undue heterogeneity; this is in line with the statistical theory on confidence intervals on index numbers expounded in Section III. Appropriate transaction-based hedonic methods for sparse data are outlined in Section IV.

Section VI concludes with a brief summary of a proposed way forward.

The motivation for this paper and flow of the argument is as follows: reliable timely measures of commercial property price inflation are essential to macroeconomic planning and financial stability. While the need for reliable RPPIs is well recognized (Heath and Goksu, 2015), standards of measurement have been established (Eurostat et al., 2013), and countries are now successfully implementing such measures for RPPIs (Hill et al., 2018) though similar progress is not apparent for CPPIs (Section V).

The need for reliable and timely CPPIs is strong but data and measurement problems using transaction data more problematic. It is argued here that the use of appraisal/valuation data based on market investments and tax assessments or REIT prices do not serve the needs of users and are likely to actually mislead them. The argument that some data is better than none is a dangerous one if the "some data" unduly smooth and lags transaction price indexes. The signal that users receive from the data is that the turning point has yet to come, when in practice the economy may have hit it, and given data that says otherwise, no action is taken. Statisticians have a responsibility to not issue misleading data. We point out that the political economy of international institutions is to react to international data demands, especially when such demands are prompted by high-profile G-20 directives. We will argue that the responsible course of action is to make use and encourage the major developments in methodology for transaction-based CPPIs that take account of the limitations of sparse data, and be transparent as to the reasons for not publishing estimated CPPIs with wide confidence intervals.

II. Alternative data sources and empirical evidence on the relationship between price indexes from these sources

Appraisal data[4]

Appraisal-based indices—the term "appraisals" is used here in a generic sense to include valuations for investment or tax assessment—have the major advantage of extending the effective sample of price observations beyond the often-sparse sample of transactions. Moreover, the extended sample of observations can be matched over time with, in principle, the price of a property being assessed, say for tax purposes, annually resulting in a panel of matched property prices over time. The larger samples and the matched panel structure of the database, with the prices of like properties compared with like, not only negates the need for quality-mix adjustments but also leads to more efficient estimates, in the sense of smaller confidence intervals, for the resulting price index measures—see Section III. However, it will be argued below that the increase in sample size is illusionary; appraisal prices are themselves based on transaction prices and carry with them the insecure foundation of a more limited sample. Further, it will be argued in Section III and shown in Section IV that the compilation of hedonic transaction-based indexes can be best formulated as a matched-paired sample.

Appraisal-based indexes have a number of serious disadvantages when contrasted with transaction-based indexes. These include:

- Appraisal-based indexes have a subjective basis that does not accord with the (transaction-based) market valuation principle of price statistics and the *System of National Accounts* (2008 SNA paragraphs (2.59) and (2.60)). The extent and nature of the bias will vary between and within countries depending on the appraisal standards used in practice. There is an extensive literature with references provided below on appraisal bias and its nature.
- Guidelines to professional appraisers are that they base their appraisal on the transactions of similar properties currently in the market, see Baum and Crosby (2008), introducing circularity in the argument that appraisals data solves the problem of sparse data. Appraisal data are often heralded as a panacea to the problem of sparse data but they only give the appearance of doing so, the assessments being grounded in sparse data.[5] This is particularly apparent when regressions are used to predict assessed

[4] Limitations outlined below are largely based on Eurostat (2017, section 4.24, pages 34–36). Silver (2013) provides a summary account of the different data sources.

[5] Royal Institution of Chartered Surveyors (RICS) (2017, pages 78-79), outlines valuation approaches and methods: "….the overall valuation approach is usually classified into one of three main categories:

- The *market approach* is based on comparing the subject asset with identical or similar assets (or liabilities) for which price information is available, such as a comparison with market transactions in the same, or closely similar, type of asset (or liability) within an appropriate time horizon.
- The *income approach* is based on capitalisation or conversion of present and predicted income (cash flows), which may take a number of different forms, to produce a single current capital value. Among the forms taken, capitalisation of a conventional market-based income or discounting of a specific income projection can both be considered appropriate depending on the type of asset and whether such an approach would be adopted by market participants.
- The *cost approach* is based on the economic principle that a purchaser will pay no more for an asset than the cost to obtain one of equal utility whether by purchase or construction.

3. Underlying each valuation approach and valuation method is the need to make such comparisons as are practically possible, since this is the essential ingredient in arriving at a market view. It may well be possible to arrive at a valuation opinion by adopting more than one approach and one method or technique, unless statute or some other mandatory authority imposes a particular requirement. Great care must be exercised when relying on the *cost approach* as the primary or only approach, as the relationship between cost and value is rarely direct.

prices from sparse actual transaction prices.

- Valuations made by an appraisal firm are largely conducted irregularly, say annually, and quarterly data may in part be (stale) estimates by the manager/owner of the property largely based on the last formal appraisal. It may be, for example, that a quarterly index compiled from annual appraisal data would include, on average and depending on reporting requirements, three-quarters of its price observations each quarter based on interpolations and all of its price change measures, based on interpolations.
- Depending on the institutional arrangements for the country, the timeliness of an appraisal index, especially if it relates to a requirement for an adequate sample size for interpolations, may be problematic.
- Information on capital expenditures and depreciation are used, in appraisal-based indices, as a means for quality adjustment between appraisals. There is much in the definition of these variables that render them inadequate as currently constructed for the needs of CPPIs.[6]
- Guideline for appraisals and definitions vary between and within countries, and substantially so.

- The sample of values is for larger professionally-managed properties—there may be a sample selectivity bias.

- The population from which the data used to create appraisal indices changes over time. Since the purpose of these indexes, as currently used in the private sector, is to capture changes in investment returns of properties, they are estimated either by taking investment properties which are owned by clients or by sampling the population. As a result, if a given property is sold off and is no longer an investment target, it is removed from the index; if a property becomes a new investment target, it becomes part of the index. In other words, the properties, which are the target of the index, change over time. Average prices of a bundle of properties are no longer compared with average prices of 'like' bundle. In this sense, these indices are not completely free from bias stemming from quality changes over time.

- There is evidence that appraisal-based indexes unduly smooth and lag prices—see Section II.

- Users for macroeconomic analysis have an established preference for transaction-based indexes. The European Central Bank (ECB), as part of a stocktaking exercise on CPPIs, asked end-users their views as to their needs: the relatively uniform response was for commercial property price index based on transaction prices; valuation indexes were, as noted by Kanutin (2013), only 'a second-best option'.

All of this is not to negate the efforts put into developing appraisal-based CPPIs. Kanutin (2013) has compiled, with due diligence, an extensive dataset of CPPIs for European countries as part of the work by the

4.Valuation methods may include a range of analytical tools or techniques as well as different forms of modelling, many of which involve advanced numerical and statistical practices. In general, the more advanced the method, the greater the degree of vigilance needed to ensure there is no internal inconsistency, for example, in relation to the *assumptions* adopted.

5. Further detail on the application of approaches and methods may be found in the *International Valuation Standards* at IVS 105 Valuation Approaches and Methods. It must be emphasized, however, that the valuer is ultimately responsible for selection of the approach(es) and method(s) to be used in individual valuation assignments, unless statute or other mandatory authority imposes a particular requirement."

[6] Most investment return indicator appraisal-based indices eliminate capital expenditures from the capital return (price change) index, and explicitly report capital expenditures on the properties each period. Capital expenditures are sometimes reported only to the extent that such expenditure brings the property back to its previous period's quality. A change in capital expenditure quality may be over and above this sum, say an extension to the building.

European Central Bank's (ECB) Working Group on General Economic Statistics (WGGES).

Empirical evidence on transaction and appraisal indexes

There is a growing literature on the nature and extent of valuation error in appraisal-property price assessments. This includes: Gallimmore and Wolverton (1997); Kinnard, Lenk and Worzala (1997); Wolverton (2000); Baum and Cosby (2008); Changha, and Gallimore (2010); Crosby, Lizieri and McAllister (2010); and Geltner, Miller, Clayton and Eichholtz (2014). The research extends to valuation bias in less-developed countries including, Awuah, Baffour, Gyamfi-Yeboah, Proverbs, and Lamond (2017) and Caleb, Durodola, Oloyede, Omolade, and Oni (2018).

CPPIs using transaction costs have been measured for some countries and where appraised prices for investment valuations, tax assessments and REITs are available this provides a valuable opportunity to examine the extent to which the alternative indexes track each other. There will remain differences in the coverage and methodologies used for the compilation/estimation of the different indexes from the different data sources, however, such differences may well be endemic to the source data and be part and parcel of the actual measure. For example, if REITs cover larger and more prestigious property holdings, or tax assessments are annual and quarterly data is interpolated, or valuations of REITs are for the (changing composition of the) portfolio, rather than individual properties, then while these differences will mar the purity of a comparison of data sources, they reflect the differences in actual measures of commercial property price inflation from appraisal/assessment and REIT data, as compared with transaction data. Where there should be concern is with failings in the coverage and methodology of transaction-based CPPI which acts as a benchmark. However, what the studies do find is a consistent smoothing and lagging of appraisal data with regard to their transaction-based CPPI counterparts.

Geltner (2015), in the context of US data, ascribes this to two phenomena:

> "First, the appraisal of individual property values reflects procedures of professional appraisal practice that tend to result in some temporal lagging bias, and properly so, as appraisers need to document their valuation estimates based on historical transaction price evidence and as they need to filter out the noise that exists in individual transaction prices (Quan & Quigley 1989, 1991). Second, although pension funds and their property investment managers are required …. to reappraise each property at some frequency, this is rarely done for all properties every quarter. Yet the NPI[7] includes all properties every quarter, including those that are not reappraised in the current quarter and that are thus reported to the index at a prior (stale) appraisal value."

There is a growing literature on the difference between transaction and appraisal-based price indexes, particularly for the US and Japan. This literature includes: Cole, Guilkey and Miles (1986); Geltner, Graff and Young (1994); Geltner (1997, 1998); Crosby (2000); Geltner and Goetzmann (2000); Bowles, McAllister, and Tarbert (2001); Clayton, Geltner, and Hamilton (2001); Geltner, MacGregor and Schwann (2003); McAllister, Baum, Crosby, Gallimore, and Gray (2003); Geltner and Fisher (2007); Horrigan, Case, Geltner, and Pollakowski (2009); Cannon and Cole (2011); and Geltner (2015) as examples of US studies indexes finding evidence of lagging, smoothing, and errors with regard to transaction-based CPPIs. Nishimura and Shimizu (2003), Shimizu and Nishimura (2006), and Shimizu, Nishimura and Watanabe (2012), Shimizu, Diewert, Nishimura and Watanabe (2013), Shimizu (2016) and Diewert and Shimizu (2017) compared transaction-based RPPIs and CPPIs with appraisal-based price indexes for Japan with similar findings.

[7] The NPI [National Property Index] is an appraisal-based index for commercial properties compiled by the National Council of Real Estate Investment Fiduciaries (NCREIF)—Silver (2013)

Shimizu and Nishimura (2006) outline the very particular institutional and cultural factors adversely impacting on residential and commercial property price measurement in Japan. In spite of this, there has been a vast research output. We take as an illustrative example recent work by Diewert and Shimizu (2017).

Figure 1 shows three price indexes for office space in Tokyo taken from the exhaustive study by Diewert and Shimizu (2017, Table 10). The PFREIT is a Fisher price index based on appraisal values of properties whose holdings are in REITs – they are not based on stock market prices themselves but on appraised values. PFMLITS is a smoothed price index based on transaction data and is compiled as a weighted average of the separate price series estimated for each of the land and structures components.[8] PFLDHEDS is again a smoothed transaction-based price index, but this time estimated without benefiting from the analytical decomposition of land and structure. PFMLITS and PFLDHEDS can be seen to be fairly similar. These two transaction indexes showed the fall into the recession in 2007Q3 and 2007Q4 respectively. However, the appraisal index would have informed the central bank and other macroeconomist that commercial property prices were not only holding up, but increasing. It was not until 2008Q3 that a downturn was signaled by the appraisal index, and then only by 0.8 percent (annual quarterly change) and continued to fall at a much lower rate than the transaction-based indexes. Indeed, the appraisal index showed commercial property prices to hardly recover for the remaining quarters of the series, to 2015Q. The appraisal-based price index increased by 11 percent from the start of the series in 2005Q1, over 10 years the 10 years of the series, while the transaction-based indexes showed prices to recover after the dip of the recession increasing at 43 and 54 percent respectively over the same period.

Figure 2 shows the same data for quarter-on-corresponding-quarter in the previous year—percentage annual quarterly changes—an indicator arguably more suitable for monitoring price changes. Again, it is in 2007Q3 and 2007Q4 that alarm bells would have rung as these indexes plummeted, as shown by the PFMLITS and PFLDHEDS, but it was only in 2008Q2 that we saw similar falls with the former indexes crossing into a negative percentage change in 2008Q1 while the appraisal index did so in 2008Q4, but with a fall of 1.4 percent contrasting with the 18 and 15 percent falls of the above two transaction-based indexes. At the trough of the fall in the commercial property prices (both in 2009Q3) the transaction-based indexes were registering falls of 25.5 and 20.2 percent while the appraisal index reaches fell by only 12.8 Percent (2009Q4).

This study is of course specific to a particular type of commercial property in a specific country, but is indicative of findings in the literature. Given such results it should be hard for statisticians to advocate for the provision of appraisal indexes.

[8]The innovative framework for the decomposition of Land and structures in property price index measurement is due to Diewert and Shimizu (2015) and Diewert, Fox and Shimizu (2016).

Figure 1: Commercial property price indexes for Tokyo offices, using transaction and appraisal data: 2005Q1=1.00 - Diewert and Shimizu (2018)

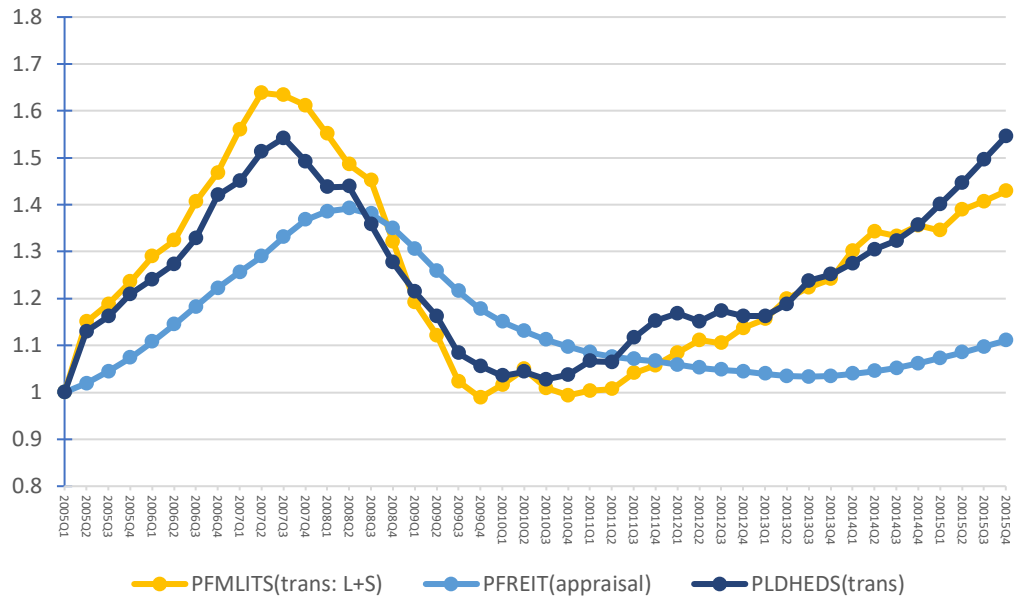
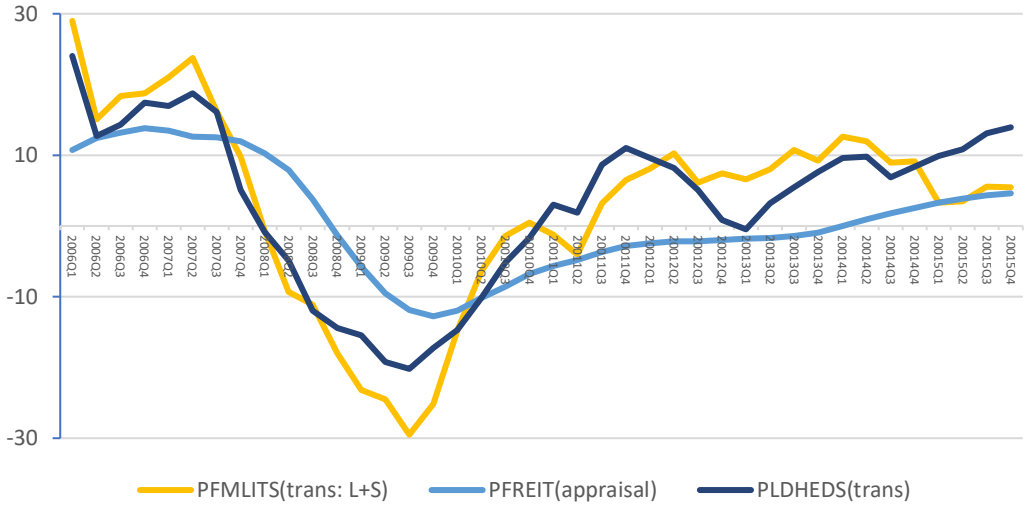


Figure 2: Commercial property price inflation for Tokyo: quarter-on-quarter annual change - Diewert and Shimizu (2018)



Real Estate Investment Trusts (REITs)

Shares in Real Estate Investment Trusts (REITs) are traded on the stock market. Their equity share prices provide data on the value of the property holdings and how the value changes over time. The resulting data

are of a very high frequency, often compiled on a daily basis. REIT holdings are commercial real estate portfolios. Most of their earnings are paid out as dividends. They have the advantages of being a readily-available high-frequency (daily) indicator that can lead the private market due to the efficiency with which trades can be made. They do not suffer from problems of thin markets and sparse transaction data. However, they have some disadvantages:

- They do not track the transaction prices of commercial properties within the private property market, but rather only indirectly reflect the valuation of such assets by investors and traders in the stock market.
- The holdings of properties in portfolios will change over time as new properties are added and existing ones sold. Changes in the stock market valuation will be in part determined by such compositional changes, though the extent to which this takes place will not be apparent to the user.
- Not all commercial properties are publicly traded. Many will be owned and traded outside of REITs in the private property markets. Commercial properties held in publicly-traded REIT portfolios are likely to be larger, on average, than properties traded in the private property market and may experience quite different price changes.

- The stock market is a more efficient vehicle for trading in commercial property, especially for enabling a quick turnover in purchases and sales. Its movements will not just reflect (a best guess at) the underlying market price, but also the "animal spirits" that can drive the stock market. The market price of a commercial property is something that is only realized when the asset itself is bought and sold in the market. The concern of CPPIs is with the price change measurement of commercial property and REIT indexes with investment returns. They are different phenomena.
- Buyers and sellers in the private market may have different priorities regarding their purchases and sales. The private market purchaser, for example may be looking for long-term returns.
- They are measures of total investment returns which include rents and other incomes, while CPPIs are price indices for commercial property as a non-financial asset whose price change is in principle the change in the market price in the current period relative to a reference period, with no account taken of income.

Empirical evidence on transaction and REIT-based indexes[9]

Figure 4 is from Geltner (2015) based on data provided in Elonen (2013). Figure 4 provides an illustrative example of the difference between a REIT-based price index and a transaction-based one for commercial property assets for Germany, quarterly from the end of 2009 through 2012. The VDP Property Price Index is a hedonic transactions-based price index of commercial property. *PureProperty* is based on publicly traded European REITs and listed property companies that hold properties in Germany, Eurostat (2017) and Elonen (2013). The three-year period covered by Figure 4 includes the initial recovery from the global financial crisis as well as the crisis in the euro in 2011, which by 2012 led to capital flight into Germany. As Geltner (2015) notes, the PureProperty index is based on "….public securities markets, a type of market in which prices reflect an equilibrium that moves very freely and quickly, responding to news and shifts in supply and demand. The private property market in which German investment institutions trade the properties whose prices are reflected in the VDP index is a much quieter and more traditional arena.". They are two different indexes operating in roughly the same markets showing quite different price changes.

[9] This account is based on Geltner (2105).

Figure 4, CPPIs and REIT-based commercial property price indexes for Germany: 2009: Q4=100.00

Stock market–based and transactions-based commercial real estate price indices for Germany. Abbreviations: REIT, real estate investment trust; VDP, Verband Deutscher Pfandbriefbanken (Association of German Pfandbrief Banks). Data are from Elonen (2013).

III. Sampling theory and confidence intervals of index number formulas

The concern with using transaction-based CPPIs is the problem of sparse data, a problem phrased in terms of small sample sizes. Yet it is the heterogeneity of the sample that compounds the problem. Errors arising from a small heterogeneous sample are reflected in statistical sampling theory by the width of the confidence interval attached to the sample estimates. The (confidence) interval estimate in which we would expect the population mean to fall 95 percent of the time is $\bar{x} \pm 1.96\,\sigma/\sqrt{n}$ where $\bar{x}$ is the sample mean, σ the population standard, deviation (to be approximated by the sample standard deviation), *n* the sample size for each randomly drawn sample, and $\sigma/\sqrt{n}$ the standard error (SE) of the sampling distribution. By the central limit theorem, the sampling distribution of the means, $\bar{x}$, is normally distributed for large samples—a rule of thumb is $n \geq 30$—irrespective of the underlying distribution of the variable x. What is important is that it is not just the sample size that determines the width of the confidence interval, but also the heterogeneity of the property prices. If all properties transacted in a quarter were of the same price, then a sample size of one would be sufficient. Conversely, if the standard deviation was very large, what might be considered to be a sufficiently large sample size may yield very large confidence intervals and imprecise estimates.

However, we do not require a confidence interval for a sample mean, but for the ratio of sample means. For the (unweighted) Dutot price index, the required ratio is of arithmetic mean prices in the current period compared with arithmetic mean of prices in the reference period. For the Jevons index the required ratio is of geometric mean prices in the current period compared with geometric mean of prices in the reference period. We consider here the Jevons index because of its better axiomatic properties.

If the sample of properties compared by the two means of prices—in the current and reference period—are *independent* samples, the Jevons index is the (exponent of) the difference between the arithmetic means in the

current and reference period of the logarithms of prices and the SE of this difference is the square root of the *sum* of the separate variances (standard errors squared) of the two samples. Thus where d_i is the difference between the logarithms of prices in the current and reference periods for property i, $d_i = lnP_{ic} - lnP_{ir}$, $\bar{d}$ the mean of these differences, $SE(d) = \sqrt{[var(P_c) + var(P_r)]}$, and the 95% confidence interval for the difference is $\bar{d} - 1.96SE(d)$ to $\bar{d} + 1.96SE(d)$—a simple illustration is provided in Altman and Bland (2003). The confidence interval for the Jevons index is simply the exponents of these lower and upper bounds on the confidence interval. As such the SE from sparse heterogeneous independent samples will be much higher than would be anticipated from simply judging what it might be based on the sample size in an individual period. It is the ratio of the means we are interested in, not the individual means, and the ratio's standard error. The implication is that the problem of sparse data is more serious than might be initially considered.

The large standard error for the ratio of the means from the two independent samples would substantially increase the confidence interval making the results from spare heterogeneous data much more imprecise than might be initially considered. Re-sampling properties transacted each period may be considered as independent sampling. The lesson here is *not* to compare (geometric) average transaction prices when you have sparse heterogeneous data. The samples are independent and the SE suffers as a result. Appraisal data does not need to use independent samples. The data are matched/paired prices for the same property in the two periods. The (exponent) of the average difference between the logarithm of these prices is the Jevons index and its SE is based on the standard deviation of these differences, much smaller than the *sum* of the SEs for the two independent samples. This argues for appraisal data and indeed gives a statistical validation to the argument for the data's matched pairs/panel structure

The question is whether transaction-based data can be used to compile a Jevons index that not only adjusts the mean prices in the current and reference periods for changes in the quality-mix of properties, but also phrases the calculation in terms of matched-paired price comparisons, rather than independent samples, so that the SE is no longer the sum of the SEs of each independent sample. The answer is "yes." The best-practice hedonic methodology, as espoused in Hill and Melser (2008), Diewert, Heravi and Silver (2009), Hill (2013), de Haan and Diewert (2013), and Silver (2018), does exactly that. The hedonic imputation approach takes transactions in the current period and then for these same matched-paired properties imputes the prices they would have sold at in the reference period. The imputation is undertaken using a hedonic regression estimated for the reference period. A similar exercise can be undertaken using a hedonic regression to impute the current period prices of reference period properties, as outlined in more detail in the next section. We thus have a quality-mix adjustment and a transference of the data away from independent samples to matched paired comparisons achieved by a leading-edge hedonic methodology.

We describe it as "leading-edge methodology" since first, international recommendations on HPI measurement methodology advocate the hedonic methodology as the preferred method for quality-mix adjustment (Eurostat, ILO, IMF, OECD, UNECE, World Bank (2013), European Commission (EC) (2017), and Hill (2013). Second, it is widely used, Hill et al, 2018), and third the imputation method benefits by having been shown to be equivalent, for quite reasonable specifications of the hedonic regression and aggregation formulas, to the characteristics approach[10] and to be readily adapted using information available in real time,

[10] A log-linear hedonic characteristics price index with constant reference-period average characteristics, $\bar{z}_k^0 = {}^1\!/_{N^0} \sum_{i \in N^0} z_{i,k}^0$,

is equals an imputation index for reference period properties:

$$P^{0 \to t}_{HGMI:\bar{z}_i^0} = \frac{\prod_{k=0}^{K} \left(\hat{b}_k^t\right)^{\bar{z}_k^0}}{\prod_{k=0}^{K} \left(\hat{b}_k^0\right)^{\bar{z}_k^0}} = \frac{\exp\left(\sum_{k=0}^{K} \bar{z}_k^0 \ln \hat{b}_k^t\right)}{\exp\left(\sum_{k=0}^{K} \bar{z}_k^0 \ln \hat{b}_k^0\right)} = \frac{\exp\left(\frac{1}{N^0} \sum_{k=0}^{K} \sum_{i \in N^0} z_{i,k}^0 \ln \hat{b}_k^t\right)}{\exp\left(\frac{1}{N^0} \sum_{k=0}^{K} \sum_{i \in N^0} z_{i,k}^0 \ln \hat{b}_k^0\right)}$$

to being weighted at the elementary level using a superlative index number formula, see de Haan and Diewert (2013), Hill and Melser (2008), and Silver (2018).

It may be argued that the use of the hedonic imputation approach to create a matched panel data structure, while an improvement on the use of comparisons of independent samples, only puts the transaction-based data set on a par with the appraisal data set in the sense that both are now compiled from matched data. The transaction-based CPPI now avoids the larger standard errors from comparing means from independent samples. Appraisal/assessment data will still have a larger sample size being available for all properties appraised/taxed, rather than the hedonic paring of those transactions in the (extended) reference period and current period. However, this larger appraisal/assessment sample size is an illusion. Such prices are based on the more limited transaction data and used in a subjective and inconsistent manner with documented bias to arrive at the appraised prices. Further, the quarterly estimates are based on extrapolations from annual estimates; the basis of, and extent to which, these extrapolations are employed is unknown to the user and can swamp measured (transaction-based) price change. If, for example, there were only four properties sold for a type of commercial property during a quarter, appraised prices in the current period for the much larger sample will be based on these four prices, never mind other biases, lags and staleness that may be part of the appraisal price-determining process outlined in Section II.

A final take-away from this section is that it is the confidence interval associated with an estimate from a sample of sparse data that matters. If the underlying transaction data is based on a small sample of transactions the confidence interval will be large and results unreliable, indeed even worse, misleading, for policy purposes. Dressing up a small sample in an abundance of appraisal prices does not negate this statistical principle.

IV. The hedonic imputation approach and matched-paired data[11]

$$= \frac{\exp\left(\frac{1}{N^0}\sum_{i\in N^0}\sum_{k=0}^{K} z_{i,k}^{0}\ln\hat{b}_k^t\right)}{\exp\left(\frac{1}{N^0}\sum_{i\in N^0}\sum_{k=0}^{K} z_{i,k}^{0}\ln\hat{b}_k^0\right)} = \frac{\prod_{i\in N^0}\left(\hat{p}_{i|z_i^0}^t\right)^{\frac{1}{N^0}}}{\prod_{i\in N^0}\left(\hat{p}_{i|z_i^0}^0\right)^{\frac{1}{N^0}}}$$

and similarly, average characteristics held constant in the current period t, $\bar{z}_k^t = \frac{1}{N^t}\sum_{i\in N^t} z_{i,k}^t$ is equal to an imputation index for current period t properties:

$$P_{HGMI:z_i^t}^{0\to t} = \frac{\prod_{k=0}^{K}\left(\hat{b}_k^t\right)^{\bar{z}_k^t}}{\prod_{k=0}^{K}\left(\hat{b}_k^0\right)^{\bar{z}_k^t}} = \frac{\prod_{i\in N^t}\left(\hat{p}_{i|z_i^t}^t\right)^{\frac{1}{N^t}}}{\prod_{i\in N^t}\left(\hat{p}_{i|z_i^t}^0\right)^{\frac{1}{N^t}}}$$

[11] The focus here is on hedonic transaction-based indexes, rather than Repeat Sales (RS) indexes. The Repeat Sales (RS) method was developed to overcome the quality-mix problem by constraining the sample of properties used in RPPI measurement to those sold more than once over the period in question. The inherent weaknesses of the RS method lies in its deletion of single-sales data, a potential lemons bias, and failure to properly account for the depreciation/improvements to properties between sales. There is also a major problem of determining how much weight should be given to pairs of price comparisons with a long time period between sales. Leventis (2008) has found differences in the autoregressive formulation of the RS model, used to weight such paired comparisons, can account for significant differences in the index results. Hedonic regression methods are now more prevalent than the RS method as a result of the increasing availability of detailed data sets of house prices and characteristics, mainly arising from the development of on-line residential property sales databases, and the development of a more sophisticated hedonic RPPI methodology (Hill and Melser (2008); Hill (2013); De Haan and Diewert (2013); Diewert and Shimizu (2017), and Silver (2018) led to the development of international standards of measurement for RPPIs (Eurostat, 2013) and the widespread development of RPPIs both in terms of the number of countries and their quality of measurement (Hill *et al*., 2018).

A log-linear hedonic regression equation[12] for (the logarithm of) prices on $z_{k,i}^t$ characteristics for period *t* data is given by:

$$(1)\ldots.\ \ln p_i^t = \ln b_0^t + \sum_{k=1}^{K} z_{k,i}^t \ln b_k^t + \ln e_i^t$$

An estimated OLS regression equation for equation (1) is given as:

$$(2)\ldots.\ \ln \hat{p}_i^t = \ln b_0^t + \sum_{k=1}^{K} z_{k,i}^t \ln b_k^t$$

where $\hat{p}_i^t$ (and p_i^t) are the predicted (and actual) price of property *i* in period *t*; $z_{k,i}^t$ are the values of each *k*=1,….,*K* price-determining characteristic for property *i* in period *t*; $\hat{b}_0^t$ and b_k^t are the estimated (and actual) coefficients for each characteristic z_k^t; ε_i^t are i.i.d. errors, using period *t* data and characteristics.

The *imputation* approach works at the level of individual properties, rather than the average values of their characteristics. The rational for the imputation approach lies in the matched model method. Consider a set of properties transacted in period *t*. We want to compare their period *t* prices with the prices of the same matched properties in period 0. In this way there is no contamination of the measure of price change by changes in the quality-mix of properties transacted. However, the period *t* properties were not sold in period 0—there is no corresponding period 0 price. The solution—in the denominator of equation (3)—is to predict the period 0 price of each period *t* property. We use a period 0 regression to predict prices of properties sold in period *t* to answer the counterfactual question: what would a property with period *t* characteristics have sold at in period 0?

A constant-quality *hedonic geometric mean imputation* (HGMI) price index is a ratio of the geometric means of prices of individual properties in period *t* compared with period 0 of properties transacted in the *current* period *t*. The value in the numerator of equation (3) is the geometric mean of the period *t* price of period *t* price-determining characteristics, $z_{i,k}^t$. This is compared, in the denominator, with the geometric mean of the **period 0** predicted price of the self-same period *t* price-determining characteristics, $z_{i,k}^t$. For each property, the quantities of characteristics are held constant at period in period *t*, $z_{i,k}^t$; only the characteristic prices change. Where N^t is the number of properties transacted in period *t*:

$$(3)\ldots..\ P_{HGMI:z_i^t}^{0\to t} = \frac{\prod_{i\in N^t}\left(\hat{p}_{i|z_i^t}^t\right)^{\frac{1}{N^t}}}{\prod_{i\in N^t}\left(\hat{p}_{i|z_i^t}^0\right)^{\frac{1}{N^t}}} = \frac{\exp\left(\frac{1}{N^t}\sum_{i\in N^t}\ln \hat{p}_{i|z_i^t}^t\right)}{\exp\left(\frac{1}{N^t}\sum_{i\in N^t}\ln \hat{p}_{i|z_i^t}^0\right)}$$

And a constant period 0 characteristics, z_i^0, hedonic imputation HGMI where N^0 is the number of properties transacted in period 0 is given by:

$$(4)\ldots.\ P_{HGMI:z_i^0}^{0\to t} = \frac{\prod_{i\in N^0}\left(\hat{p}_{i|z_i^0}^t\right)^{\frac{1}{N^0}}}{\prod_{i\in N^0}\left(\hat{p}_{i|z_i^0}^0\right)^{\frac{1}{N^0}}} = \frac{\exp\left(\frac{1}{N^0}\sum_{i\in N^0}\ln \hat{p}_{i|z_i^0}^t\right)}{\exp\left(\frac{1}{N^0}\sum_{i\in N^0}\ln \hat{p}_{i|z_i^0}^0\right)}\ .$$

[12] Triplett (2006) provides a thorough overview of the concepts and methods of hedonic regressions.

We use predicted prices in both the numerators and denominators of equations (3) and (4): a dual imputation. For example, in equation (3) the single imputation index could be defined to use the actual price in the numerator and predicted price in the denominator. The denominator is a counterfactual price that a transacted property in period *t* would have sold at period 0; a hedonic regression in period 0 is required.

Yet a feature of the ordinary lest squares (OLS) estimator is that the mean of actual prices is equal to the mean of predicted prices:

(5)…. $\frac{1}{N^0}\sum_{i\in N^0}\hat{p}^0_{i|z_i^0} = \frac{1}{N^0}\sum_{i\in N^0} p_i^0$ and $\frac{1}{N^t}\sum_{i\in N^t}\hat{p}^t_{i|z_i^t} = \frac{1}{N^t}\sum_{i\in N^t} p_i^t$.

Thus, while the denominator of equation (3) must be counterfactual and use predicted prices, the numerator of equation (3) can use actual prices. Thus, when using un-weighted hedonic imputation indexes there is no need to estimate hedonic regressions in each period for (3), actual prices can be used in the numerator.

Equations (3) and (4) can be seen to take the form of **matched-paired data**, rather than independent samples with the actual (or predicted) price of property *i*=1 in equation (3), for example, in the numerator compared with the counterfactual price of what this same property, that is one with identical characteristics as specified in the hedonic regression, would have sold at in period 0, as predicted by the estimated hedonic regression equation. The summation sign encompasses all properties transacted in period *t* and their imputed period 0 prices.

Tweaking the hedonic methodology for sparse data

Use an HPI methodology that only require a hedonic regression to be estimated in the reference period.

The proposed measure below is a hedonic imputation based only on a sample of period *t* transactions. Equation (3) above only requires a hedonic regression to be estimated in the reference period 0 so that properties from the sample of transactions in period *t* with their associated characteristics can be valued in period 0—the denominator. While predicted prices are shown in period *t* for the numerator, actual prices will suffice as shown by equation (5) above.

Limiting the regression estimation to the reference period is a major advantage. Hedonic regression estimates are subject to the vagaries of specification and estimation procedures, particularly in thin markets. A requirement to estimate in each period a new hedonic regression not only opens the estimation and compilation of HPIs up to both the vagaries of rushed hedonic estimation but also to an increased delay in publication.

Use an extended period for the reference period.

The reference period should be over an extended period, rather than a quarter. First, there may not be an adequate number of observations and/or variation in the characteristics of the sample of properties transacted in a say quarterly reference period to enable reliable and pertinent estimates to be made of the coefficients of price-determining characteristics that define properties sold in the current period *t*. For example, there may a relatively small number of offices sold in a prime location in period *t*, but none sold in a quarterly reference period 0, for example 2019:Q1=100.00. An extended period 0 regression will be more likely to better encompass the characteristics of period *t* properties as well as basing the regression on a larger sample size providing coefficient estimates with more degrees of freedom.[13]

[13] The advantage of not having to re-estimate a hedonic regression on a periodic basis is well recognized by NSIs in Europe. The repricing variant of the characteristics approach used by eight countries has an extended reference period of a year to establish the average values of the characteristics and the commensurate estimated marginal values from the hedonic regression. The repricing approach allows for this due to its correspondence to the characteristics approach and equivalence to the imputation approach when crafted following the principles in section III Table 1.

There are thus many advantages to the use of a say reference period of say the whole year of 2019 (=100) as the database for the hedonic regression, with a hedonic regression re-estimated on an annual basis, or every two years allows a CPPI to be compiled as a chained index, linking together the quarterly component sub-indexes, for example, 2021=100.00, 2023=100.00, etc. by successive multiplication. The desirable duration of the reference period and the frequency with which the reference period is updated can be based on exploratory work with initial experimental CPPIs compiled using reference periods with different durations and updated at different frequencies.

Use weights at the elementary level

A benefit of matched-paired data is that weights can be applied at the elementary level. The expenditure weight for an individual property is its relative price and data on relative prices exist in real time for each property and can be applied to each respective property's price change.[14] The weighted version of equation (3) is given by equation (6) below as a quasi-hedonic formulation of a Törnqvist index.

(6)….

$$P^{0\to t}_{QToHGMI:z_i^0} = \prod_{i\in N^0}\left(\frac{\hat{p}^t_{i|z_i^0}}{\hat{p}^0_{i|z_i^0}}\right)^{\hat{w}_i^t} = \exp\left(\sum_{i\in N^0}\hat{w}_i^t \ln\left(\frac{\hat{p}^t_{i|z_i^0}}{\hat{p}^0_{i|z_i^0}}\right)\right) = \exp\left(\sum_{i\in N^t}\hat{w}_i^t \ln\left(\hat{p}^t_{i|z_i^0} - \hat{p}^0_{i|z_i^0}\right)\right)$$

where $\hat{w}_i^t = \frac{1}{2}\left(\frac{\hat{p}^t_{i|z_i^t}}{\sum_{i\in N^t}\hat{p}^t_{i|z_i^t}} + \frac{\hat{p}^0_{i|z_i^t}}{\sum_{i\in N^0}\hat{p}^0_{i|z_i^t}}\right)$, an index that has excellent properties in economic theory as a superlative index. It is "quasi" in the sense that it does not make use of the sample of period *t* transactions. It is "superlative" in the sense that the index of price changes of transactions undertaken in period 0 makes symmetric use of reference and current period price information (Diewert, 1976 and Balk, 2008). Silver (2018) shows how a weighted version of equation (4) can also be formulated as can a superlative index that makes use of both base period 0 and current period *t* transactions as the two weighted versions of equations (3) and (4) are put together as a weighted average to form a Törnqvist hedonic imputation index for the full sample.

There are other methods of measuring property price indexes where there are sparse transactions and the reader is referred to Goetzmann (1992), Geltner (1993), Bokhari and Geltner (2012) and Silver and Graf (2014). There may be no easy solution, but it must not be for lack of serious research that can, at the very least, identify and surmount some methodological pitfalls and confront others with eyes wide open.

V. The institutional setting

This section outlines the institutional setting for the development of CPPIs. While the primary work on developing and compiling regular CPPIs will fall on national statistical offices, central banks and, to a lesser extent, private and quasi-governmental organizations, the responsibility for establishing measurement standards and promoting the methods lies with the international organizations. The primary institutional initiative under which global standard setting for CPPs is promoted is the G-20 Data Gaps Initiative (DGI). In April 2009, the Group of Twenty (G-20) Finance Ministers and Central Bank Governors (FMCBG) Working Group on Reinforcing International Co-operation and Promoting Integrity in Financial Markets called on the International Monetary Fund (IMF) and the Financial Stability Board (FSB) to explore information gaps and provide appropriate proposals for strengthening data collection and report back to the Finance Ministers and Central Bank Governors. This call was endorsed by the IMF's International Monetary

[14] A similar procedure can be applied to appraisal-based indexes though has not, to the author's knowledge, been used.

and Financial Committee (IMFC). The work is coordinated by the Inter-Agency Group on Economic and Financial Statistics (IAG) which comprises representatives from the Bank for International Settlements (BIS), the European Central Bank (ECB), Eurostat, the IMF, Organisation for Economic Co-operation and Development (OECD), the United Nations, and the World Bank.

The first Report was on October 29th 2009 and listed 20 recommendations to address information gaps revealed by the global financial crisis, one of which was real estate indicators. Work on the DGI focused on the RPPI making considerable progress including the development of methodological standards, *Handbook on Residential Property Price Indices* (*RPPIs*), published in April 2013 (Eurostat et al., 2013), and a considerable uptake in country practice, currently 60 countries.

There is another group that is responsible for international standards on price statistics. This is the Inter-secretariat Working Group on Price Statistics (IWGPS) comprising representatives from Eurostat, ILO, IMF, OECD, UNECE, and the World Bank. This is a Group that reports to the United Nations Statistics Commission (UNSC). All Manuals and Handbooks must be approved by the IWGPS before going to the UNSC for final approval. There is some overlap in membership of the IWGPS and IAG, though in practice it is the author's experience that the two bodies have worked productively together.

Given this progress, in September 2015, its sixth year, the G-20 FMCBG closed the first act (DGI-1) and opened a second act of the DGI (DGI-2)—Heath and Goksu (2015). DGI-2 recommendations II.17 and 18 addresses the development of RPPIs and CPPIs respectively. The BIS is the lead agency on CPPIs: Recommendation II.18.

Recommendation II.18 on Commercial Property Prices is:

> "The IAG in collaboration with the Inter-Secretariat Working Group on Price Statistics to enhance the methodological guidance on the compilation of Commercial Property Price Indices (CPPI) and encourage dissemination of data on commercial property prices via the BIS website." (IMF and FSB, 2015, page 40).

This shift in focus towards CPPIs was prompted by both an appreciation of their importance, the lack of methodological standards, and the small number of countries disseminating CPPIs:

> "Commercial Property Price Indices (CPPI) are at a less developed stage, both conceptually and in terms of available data. To this end, methodological guidance for the compilation of commercial property prices indices is being drafted and expected to be finalized in 2015. However, unlike the guidance for RPPI, there remain significant differences" (IMF and FSB, 2015, pages 39–40).

However, by the Progress Report of September 2018 matters had not significantly improved. Table 1 of the Report is a dashboard of achievements—Overall Implementation Status and Progress for the DGI-2 Recommendations. While "10 G20 economies report CPPI data" and "*CPPI Sources, Methods and Issues* was published in December 2017 by Eurostat," are listed as *Fully or completed workstream*; "No harmonized methodological framework nor detailed methodological guidance available yet. Action plan still to be elaborated" are included as *Early stages of implementation or lack of timely progress*. IMF and FSB (2018, page 9).

The Traffic light monitoring dashboard for Recommendation II.19 is less than inspiring with 10 of the G-20 countries boxes shaded in red (*target of publishing a CPPI not met*, and 9 in green, *target met*, the Euro area being *partially met*, orange).[15]

Of note is the summary of the Conference on RPPIs and CPPIs organized by the IMF in coordination with the BIS, Eurostat, and the OECD, and hosted by Instituto Nacional de Estadística y Censos de la República Argentina in Buenos Aires, during January 29–30, 2018:

> "The participants agreed that the way forward with real estate statistics, especially CPPI, should be pragmatic, data-oriented, and take account of available private data sources for economies where no official indicators exist." IMF and FSB (2018, paragraph 5).

So, what is the take-home from all of this? Major decisions on international standards are taken by international organizations, though these in turn, through the UNSC and other fora, are responsible to its member countries. The pressure by DGI-2 is to resolve the methodological crisis and turn the red boxes in Table 1 to green. This can most quickly be undertaken by adopting appraisal-based commercial property data. For European countries (Kanutin, 2013 and subsequent papers) such indexes are effectively up and running.

A more measured approach, as will be proposed below, will be more problematic. At the end of this conference there is a summary session from which the next IMF and FSB Report on DGI-2 Progress will include a section. So, we turn to a proposed way forward.

VI. A proposed way forward

Transaction-based CPPIs should be the recommended methodology.

They should only be used for market segments that have a sufficient sample size, where "sufficiency" considers both the dispersion (heterogeneity) of the sample and its size and follows the statistical principles of section III above. Compiling agencies should act transparently and responsibly by monitoring sample sizes and the dispersion in (the difference between matched) prices to inform users as to why indexes are constrained to particular market segments, as necessary. The proposal is that CPPIs should be provided to inform rather than mis-inform policy makers and statistical offices should be guided by statistical principles in doing so.

Transaction data CPPIs are based on new samples of transactions each period, the current period sample mean price is compared with the reference period sample mean price. This ratio, be it as an arithmetic or geometric mean, is (i) tainted by changes in the quality-mix of the sample and (ii) has an excessively wide confidence interval, as a ratio of means of two independent samples, as explained in Section III. It is proposed that such ratios of means not be used, even when there is some (minimal) quality-mix adjustment, such as price per square foot.

The proposed hedonic imputation methodology takes account of both concerns (i) and (ii) above.[16] The hedonic approach is designed to take account of quality-mix changes. The specification of the hedonic

[15] IMF and FSB (2018, Annex 2): Monitoring Traffic Light Dashboard: Status of Progress in 2018 in the Implementation of the DGI-2.

[16] Hill (2013, 906) concludes his survey paper: "Hedonic indexes seem to be gradually replacing repeat sales as the method of choice for constructing quality-adjusted house price indexes. This trend can be attributed to the inherent weaknesses of the repeat sales method (especially its deletion of single-sales data and potential lemons bias) and a combination of the increasing availability of detailed data sets of house prices and characteristics, including geospatial

regression is expected to improve over time as more characteristic and spatial (locational) data becomes available, as is likely in this digital age. There will be a natural synergy with the RPPI measurement team. The CPPI team should be able to blend expertise, software, dissemination practice gained from the RPPI practice. The *imputation approach*, as outlined above, transforms the calculation from the difference between mean of the logarithms of independent samples, whose exponent is the ratio of geometric means—a Jevons index—to a panel data set for each property transacted where the standard error is calculated as the standard deviation of matched pairs, as outlined in Section III. This substantially reduces the standard error of the estimated price index change.[17]

The hedonic imputation method can be readily applied with weights at the level of the individual property transaction and, further, such weighting system can take a superlative form as outlined in Hill and Melser (2018), de Haan and Diewert (2013), and Silver (2018)—Section III.

The transaction-based CPPI with sparse data can further benefit from using an extended time period for the reference period, as advocated by de Haan and Diewert (2013) and Silver (2018)—Section III.

The transaction-based CPPI with sparse data may also benefit from estimating the hedonic regression periodically, say annually or every two years, and chaining the results. The regular estimation of a hedonic regression every say quarter, using sparse data, leaves the index results open to bias from undue influence and other vagaries of econometric estimation. Compilers further benefit from using an extended time period for the reference period, as advocated by de Haan and Diewert (2013) and Silver (2018). Such indexes can take a quasi-superlative form as explained in Silver (2018)—Section III.

It may be argued that the use of the hedonic imputation approach to create a matched panel data structure, while an improvement on the use of comparisons of means from independent samples, only puts the transaction-based data set on a par with the appraisal data set in the sense that both are now compiled from matched data.The transaction-based CPPI now avoids the larger standard errors from comparing means from independent samples. It may be argued that appraisal/assessment data will still have a larger sample size being available for all properties appraised/taxed, rather than the hedonic paring of those transactions in the (extended) reference period and current period. However, this larger appraisal/assessment sample size is an illusion. Such prices are based on the more limited transaction data and used in a subjective and inconsistent manner with documented bias to arrive at the appraised prices. Further, the quarterly estimates are based on extrapolations from annual estimates; the basis of, and extent to which, these extrapolations are employed is unknown to the user and can swamp measured (transaction-based) price change.

An important role of international organizations with regard to economic statistics is to meet the needs of data initiatives such as the DGI, as outlined in Section V, by setting and promoting standards of measurement. However, in this case, doing something, rather than nothing, may be to mislead, rather than lead, and that would be a disservice to central banks and macroeconomists, especially when an alternative transaction-based methodological approach is available for sparse data, albeit one that requires more effort and care in its development.

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data, increases in computing power, and the development of more sophisticated hedonic models that in particular take account of spatial dependence in the data." Alternative methods are the repeat sales method, mainly used in the United States, and the sales price appraisal method (SPAR), outlined and surveyed in Eurostat *et al.*, (2013). A survey and evaluation of the impact of methods is in Silver (2015).

[17].

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