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Efficacy of Using Producer Price Indexes for Bulk Chemical Prices in Student Design Projects

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Session XXXX

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Abstract

Engineering students are being asked to work on real-world projects and need to access accurate cost information for their design projects. In the case of chemical engineering and related disciplines, capstone courses often require designing industrial processes or a chemical plant involving bulk chemical prices for both feedstocks and products. A lot of chemical pricing information was available in trade magazines; however, bulk chemical prices are increasingly difficult to locate as producers of that information have reduced the availability and further monetized the information over the last 15 years. The resulting information sources containing chemical prices often cannot be acquired by academic libraries due to cost or licensing terms. In cases where current chemical prices are not available, one could use a Producer Price Index (PPI) to adjust an older price to current levels. Using older prices and adjusting to current levels allows students access to a much larger source of chemical prices (i.e., older issues of trade magazines). Using the PPI to adjust chemical prices will be reviewed. In theory, adjustments using a PPI should provide reasonable estimates of chemical prices. To determine the efficacy of this approach, this study examined price adjustments from two chemical pricing sources for 2, 5, 10, and 15-year intervals for a group of industrial chemicals to determine the efficacy of this approach. This study then discusses the relative merits and limits of using PPIs to adjust chemical prices to assist students with their design projects.

Introduction

Obtaining bulk (or commodity) chemical prices is necessary for process design and estimating operating costs in chemical and industrial engineering. Locating chemical prices has always been challenging, but it has become increasingly difficult over the last 15 years as trade magazines publish fewer chemical prices. One solution to the dearth of current chemical prices is to use a Producer Price Index (PPI) to adjust older prices to the present. Using PPIs in this manner greatly increases the chemical prices available since many more were offered prior to 2006 in the trade literature. The objective of this paper is to demonstrate the use of the PPI and examine the efficacy of using PPIs to adjust older chemical prices. This article is written for engineering educators, engineering students, and engineering librarians to demonstrate the use of PPIs and its efficacy.

Background and Literature Review

Chemical Prices

There are two important concepts that must be considered prior to any discussion about bulk chemical prices. One is that prices paid for laboratory quantities (grams and kilograms) are significantly different compared to prices paid for bulk chemicals (tons) that are used in industrial processes. One cannot just extrapolate laboratory prices, which are readily available online through various laboratory chemical suppliers like Alfa Aesar or Sigma-Aldrich, to obtain a reasonable bulk chemical price. Extrapolating laboratory prices in this manner will result in bulk chemical prices that differ by an order of magnitude or more. The other concept is that bulk chemical prices lack a certain exactitude due to several factors. Bulk chemical prices can vary considerably due to source location, grade, terms of sale (contract versus spot), delivery, and data source to name a few, so all published values are estimates.[1,2] It is also not uncommon for buyers to enter into long-term contracts with suppliers, which may differ considerably from published sources.[2] For example, the August 2006 bulk ammonia spot prices were $257/metric ton from Tampa, Florida and $297/metric ton from New Orleans, Louisiana, a difference of 16%.[3] Another example is styrene, where the December 2008 contract price was $0.56/lb and the spot price was $0.41/lb, a difference of 37%, and an instance of the contract price being higher than the spot price.[4] Instead of a correct answer, it may be better to think about chemical prices in terms of what is reasonable and acceptable. All chemical pricing information should be viewed as estimates, even the best published sources, and therefore using a PPI to adjust an older price could be viewed as just another estimate.

Sources of Bulk Chemical Prices

A brief history of chemical pricing sources can be found in Hubbard.[5] It suffices to say that there has been considerable consolidation and increased monetization of bulk chemical pricing information within the industry over the last 15 years. The result has been less chemical pricing information available to students and researchers in the trade literature, which has historically been a major source of chemical prices. The two main companies providing chemical pricing information to industry are ICIS and IHS. Many of the services and products from these two companies are priced and licensed in a manner that prohibits academic libraries from acquiring access, though ICIS and IHS continue to publish more limited chemical prices in two trade magazines titled *ICIS Chemical Business* (formerly *Chemical Market Reporter*) and *Chemical Week*, respectively. Both *ICIS Chemical Business* and *Chemical Week* are accessible through direct subscription or through a third party (e.g., EBSCO, ProQuest, LexisNexis) at many academic libraries. These two trade magazines remain important sources of bulk chemical pricing information and should be consulted first for chemical prices unless a better source is known. Additional sources for chemical prices are found in Hubbard based on a content analysis of research guides – webpages created by librarians listing information resources on specific disciplines or topics – containing chemical pricing sources.[5] Three chemical pricing research guides cited by other research guides are hosted by Cornell University,[6] Texas A&M University,[7] and University of Texas,[8] thus serving as important lists of chemical pricing sources themselves and worth consulting. Many of the resources listed on those research guides will be subscription resources, so it is important to check access via your local library to see if you have access to those listed and possibly some unique resources containing chemical pricing information (e.g., IHS Chemical Economics Handbook, Bloomberg's Datastream, Intratec, etc.). An additional strategy for finding chemical pricing information includes keyword searching books, journal articles, and other trade magazines via bibliographic databases (e.g., ABI/INFORM., Business Source Ultimate, Nexis Uni, or WorldCat) using the name of the chemical and either "cost" or "price" as keywords. Lastly, the same keyword approach could be performed in Google Scholar and Google Books, though this can often be a fool's errand yielding a lot of false results.

Even so, the author has had some limited success locating chemical prices in journal articles and books using this last approach.

Producer Price Index (PPI) and Adjusting Chemical Prices

The PPI "…measures average changes in prices received by domestic producers for their output" and is calculated by systematic sampling of prices received for goods and services by producers (p. 1).[9] There are over 10,000 individual PPIs published monthly by the U.S. Bureau of Labor Statistics (BLS) that cover almost all sectors of the U.S. economy.[10] Additional information on the methods used to develop the PPI and its use can be found in Chapter 14 – Producer Price Indexes in the *BLS Handbook of Methods*.[9] Most of the PPIs for chemicals are general [e.g., Chemicals and Allied Products (WPU06)] or for a particular class of chemicals [Aromatics (WPU06140197)], whereas a few are quite specific [e.g., Sulfuric Acid (WPU0613020T1)]. A hierarchal list of PPIs related to the chemical industry is available online from the Federal Reserve Bank of St. Louis at the following website: https://fred.stlouisfed.org/release/tables?rid=46&eid=142872. Unlike chemical equipment or plants where it is recommended to limit cost index adjustments to no more than 10 years,[11,12] the BLS states that there is no such limitation for commodity PPIs.[13] Since BLS PPIs are based on actual prices received by chemical producers, factors such as supply/demand, technological improvements, etc. are figured into the PPI. The "basket of goods" that is used for a PPI − like Aromatics (WPU06140197) − can change over time, so one does need to be cognizant of that possibility.

Using the PPI to adjust older chemical prices for process design projects is infrequently discussed compared to the use of equipment cost indices (e.g., the Chemical Engineering Plant Cost Index or Nelson-Farrar). Upon perusal of ten standard texts containing chemical process economic information, only two discussed using PPIs to adjust older chemical prices in any substantive way (Appendix A). Brown specifically describes using PPIs to adjust older chemical prices and provides an example (pp. 36-37).[14] El-Halwagi also mentions using the PPI in terms of the time value of money (p. 41) and then later to adjust chemical product costs cited in older studies to compare process pathways (p. 553).[11] Additional examples of using the PPI to adjust older chemical prices can be found in the peer-reviewed journal literature.[15,16,17,18,19] It should also be noted that the "Producer prices, industrial chemicals (1982 = 100)" listed in the "Economic Indicators" section of the trade magazine *Chemical Engineering* is a BLS PPI. Brown states that the accuracy of such operating cost estimates are ±50% based on his experience, though this was in regard to estimating operating costs generally and not specifically chemical prices.[14] Using the five levels of cost estimates [order-of-magnitude (over ±30%), study (±30%), preliminary (±20%), definitive (±10%), and detailed (±5%)], Peters et al. placed the estimation error for raw material costs at over ±30%.[12]

Using older chemical prices and then adjusting with a PPI increases the number of available chemical prices dramatically. For example, prior to March 28, 2005 the *Chemical Market Reporter* (now *ICIS Chemical Business*) regularly published 100s of chemical prices in each issue. As outlined above, there is precedent for using PPIs to adjust older chemical prices for chemical process design projects. While certainly not a novel approach, using PPIs in this manner is seldom discussed in the chemical engineering literature. Given the dearth of current bulk chemical prices available to students and faculty, it probably should be discussed more in standard texts. The objectives of this paper are to draw attention to using PPIs to adjust older chemical prices and to examine their efficacy using a small set of examples. Considering the paucity of information on using PPIs in this way, this paper could be shared with engineering students to provide needed background on PPIs and their use.

Methods

Chemical prices were obtained from published sources for four industrial chemicals and adjusted using PPIs at periodic intervals over a 15-year period. The efficacy of the price adjustments was then assessed by comparing the deviations of the adjusted prices to reported values and ranges. The four industrial chemicals examined in this study are: ammonia, ethylene, soda ash, and styrene. The prices were obtained from two sources: *Chemical Week* and *USGS Commodity Summaries*. Prices were collected for 2003, 2005, 2008, 2013, and 2018 from those sources. For *Chemical Week*, spot prices were used rather than contract prices. In some cases, the spot price was extrapolated from a graph or an average of a price range. It should also be noted that *USGS Commodity Summaries* prices for ammonia and soda ash are unit values (estimated total value divided by total produced, rather than a spot or contract prices). The USGS unit value may be at the lower end of the actual market value.[20] Another aspect regarding the USGS unit values is that they are yearly averages, whereas the *Chemical Week* prices used are based on a given month.

The chemical prices from 2003 were used as the base year for price adjustments (Figure 1). The prices for each chemical were adjusted using three different PPIs for comparison. One of the PPIs used for all four chemicals is the Chemicals and Allied Products (WPU06). The second PPI was either the Basic Inorganic Chemicals (WPU0613) or Basic Organic Chemicals (WPU0614). The third PPI was unique for each of the four chemicals and the most specific PPI. The price adjustments were calculated and graphed for all four chemicals. The percent difference between the reported price and adjusted price were then calculated. In addition to comparing the PPI-adjusted prices to the range of reported prices for each chemical, the percent differences were used as a basis to assess the efficacy of this approach. More specifically, the estimation error will be discussed in terms of Brown's ±50%, rather than the order-of-magnitude of "over ±30%" that Peters et al. mentions.[12,14]

Older Chemical Price x [(PPI at Current Date) / (PPI at Older Date)] = Updated Chemical Price

Example: $0.295/lb[1] x [(316.5[2]/128.9[3])] = $0.72/lb

[1] Anonymous, 2003, "CW Price Report," Chemical Week, Vol.165, No. 35, p. 28.
[2] PPI - Chemicals and Allied Products: Aromatics (WPU06140197) for January 2018
[3] PPI - Chemicals and Allied Products: Aromatics (WPU06140197) for October 2003

Figure 1. Price Adjustment Formula with Styrene Example

Results

The figures and tables containing the adjusted prices and percent differences compared to published values are all presented in Appendix B. This section will report on styrene and summarize findings for the others. Figure 2 shows the reported and adjusted prices for styrene. The PPIs used for styrene were: Chemicals and Allied Products (WPU06)(C&AP), Basic Organic Chemicals (WPU0614)(BOC), and Aromatics (WPU06140197)(A).

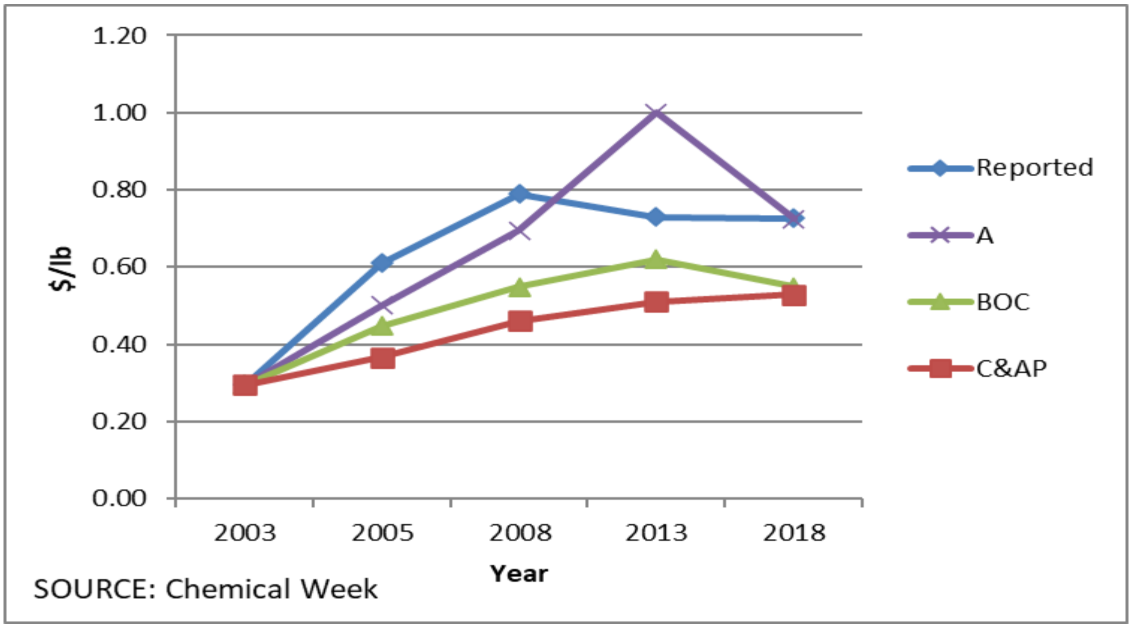

Figure 2. Styrene Reported and Adjusted Prices

The reported styrene price for the period studied was between $0.30/lb and $0.79/lb, so there were considerable price changes over the 15-year period. The adjusted prices were between $0.37/lb and $1.00/lb. All but one of the 12 PPI-adjusted prices were between $0.30/lb and $0.79/lb. In general, all three PPIs tracked the reported price curve rather well except for the PPI-Aromatics in 2013. Another observation is that the adjusted price curves were ordered from the more general at a lower adjusted price to the more specific PPIs at a higher price (i.e., the more general C&AP is on the bottom, then BOC, and finally A at the top). This latter observation was generally true for the other three chemicals as well.

Table 1. Percent Differences for Reported Versus PPI-Adjusted Prices for Styrene

Year	A	BOC	C&AP
2003	NA	NA	NA
2005	18%	27%	40%
2008	12%	31%	42%
2013	37%	15%	30%
2018	0%	24%	27%
Avg	17%	24%	35%
Hi	37%	31%	42%
Low	0%	15%	27%
Annualized	10%	6%	5%

Table 1 shows the percent differences between the reported and adjusted prices for styrene. The adjusted price differences varied between 0% and 42%. The more specific PPI-Aromatics resulted in the most accurate overall (average) adjusted prices compared to reported prices. In this example, the accuracy of the adjusted prices increased from the more general to more specific PPIs. That was not the case for the other three chemicals studied, which are discussed later.

The accuracy of the PPI-adjusted prices in this study are evaluated based on the price ranges observed and percent differences compared to reported prices. As reported in the literature, the accuracy of such estimates may vary from ±50%.[14] Using that criterion, all the adjusted styrene prices fell within ±50% of the reported price. One of the largest discrepancies between the PPI-adjusted and reported styrene prices occurred during 2013 using PPI-Aromatics. Looking at the PPI-Aromatics chart for 2003 to 2018, we see very high PPI values from March 2011 to July 2014 (Figure 3). This may have resulted in overestimating the 2013 price. Comparing Figure 3 and Figure 4, which are the PPI-Aromatics and PPI-Chemical & Allied Products, Figure 4 is relatively flatter from May 2011 to December 2018. While it is generally best to select the most specific PPI available, a more specific PPI consists of a "smaller basket of goods," and therefore may be more sensitive to individual price changes than a more general PPI composed of more chemicals (i.e., a "larger basket of goods"). Also note how the general PPI (Figure 4) is more moderated with fewer extreme peaks and valleys.

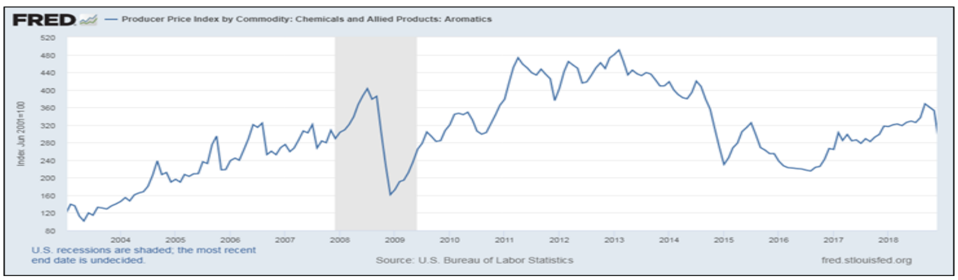

Figure 3. Producer Price Index: Aromatics (2003-18)

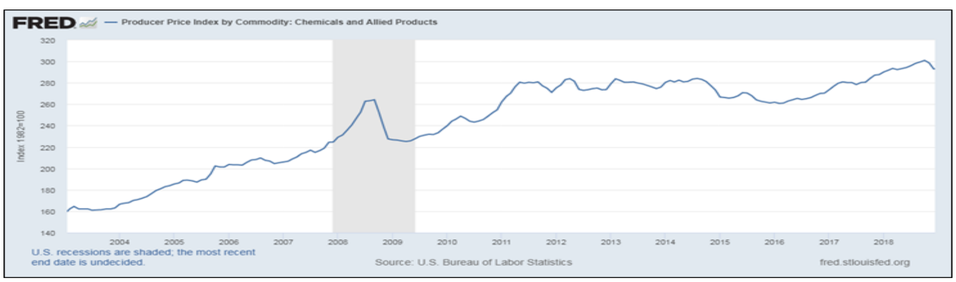

Figure 4. Producer Price Index: Chemicals and Allied Products (2003-18)

The other three chemicals studied yielded mixed results in terms of being within ±50% of the reported price or within the 2003-2018 historical price range (Appendix B). Soda Ash was the most accurate with adjusted prices of 26% or less for all three PPIs, though only half (six) of adjusted prices fell within the 2003-2018 reported price range. All three PPI-adjusted prices for soda ash tracked the actual reported values the closest of the four chemicals studied. Ethylene saw the largest PPI-adjusted price difference due to a sharp price drop in 2018 that none of the PPI-adjusted prices matched; however, the more specific PPI Petroleum Refineries: Primary Product (PP) did turn sharply downward for 2018 though overall the more specific PPI resulted in overestimating the 2018 price. Aside from the 2018 price difference, the PPI-adjusted prices for ethylene were within 35% or less of the reported value. Ten (or 83%) of the PPI-adjusted prices for ethylene were within the

2003-2018 reported price range. Turning to ammonia prices, the more specific PPI Ammonia resulted in adjusted prices that were within 36% or less of reported prices. Ammonia also experienced a sharp price drop in 2018 that was tracked better by the more specific PPI than the other two PPIs. Overall, 43 of the 48 (or 90%) of the adjusted prices were ±50% of reported prices. In over half the cases, the PPI-adjusted prices were ±25% or less of reported prices. Of the 48 PPI-adjusted prices, 39 (or 81%) fell within the reported 2003-2018 price ranges for each of the four chemicals; most of those that fell outside the reported price range (6 of the 9) were for soda ash that had generally good PPI-adjusted prices at 26% or less of reported prices.

Discussion

As indicated in the Literature Review, bulk chemical prices can be quite variable. The most accurate prices would come directly from price quotes provided by chemical manufacturers, though again these prices may vary from one producer to another. Chemical manufactures do not generally provide price quotes for student or research design projects; it does not lead to a sale and shares information that some companies might want to keep confidential. Consequently, the main source of chemical prices for student design or research projects are trade magazines, and to a lesser extent the journal literature and handbooks, though those sources are often citing the trade literature. Some specialized business sources may also be an option at some universities.

If current prices are not available from the trade literature or other sources described earlier, then using a PPI to adjust an older price is a reasonable and acceptable approach. In this study, the four chemicals and the three PPIs used resulted in reasonable values for 90% of the adjusted prices as compared to the published values ±50%.

Three different PPIs were used to adjust the prices at three levels of specificity for each chemical. It would seem logical to select the most specific PPI possible (e.g., PPI-Ammonia), but it may be worthwhile to try others at a higher level of aggregation (e.g., PPI-Chemical & Allied Products). As noted in the Results, there was no apparent pattern in which PPIs yielded better results in terms of percent differences though the more specific PPIs seemed to track the price curves more closely (i.e., the ups and downs). Sometimes it was the more general PPI-adjusted price that was closer to the reported price, other times it was the more specific PPI that was closer. Experimenting with more than one PPI for a particular chemical may give more confidence in one PPI over another by highlighting possible issues, as was the case for the 2018 PPI-adjusted prices for ammonia and ethylene due to price drops.

When adjusting chemical prices with PPIs, consider the following:

1. Find as many prices as possible to get a sense of the price range.
2. Experiment with more than one PPI (e.g., one general and one specific).
3. Examine the PPI chart and get a sense of areas of very high PPI changes.
4. Consider avoiding older prices from or adjusting prices to times of very high PPI changes.
5. Remember that almost all bulk chemical prices are really just estimates.
6. Ask yourself if the PPI-adjusted price obtained is reasonable given the above.

Raw material costs account for 50-80% (organic) and 30-50% (inorganic) of the total manufacturing expense in the chemical process industry, so ideally one should use the most accurate chemical prices available to estimate operating costs.[1] How raw material cost estimates impact design selection depends on the processes examined. If the processes being considered all use the same raw materials and produce the same product, the impact on design selection will most likely be minimal. On the other hand, if different raw materials are used to produce the same product, price estimates that are on the high end for one chemical and low end for the other chemical, may impact design selection. The greater lesson for students may be that imperfect information is not unusual in actual practice and to understand how those uncertainties might impact their design selection.

Limitations

There are many limitations to this study. This study only examined four chemicals at five intervals (2003, 2005, 2008, 2013, and 2018). More frequent time periods or different years of coverage might yield different results, as would including other chemicals. Some prices were extrapolated from graphs or averaged if a price range was given. That extrapolation and averaging could add some error. Direct chemical price comparisons were also challenging with the data available and used for this study. For example, the *USGS Commodity Summaries* data was an annual price and the PPI had to be annualized, whereas the *Chemical Week* prices were adjusted based on a more specific monthly basis. The efficacy of this approach was predicated on a percent difference that was rather large (±50%) based on Brown.[14]

Conclusion

Obtaining bulk (or commodity) chemical prices are becoming increasingly difficult to locate for student and researcher process design projects. Using PPIs to adjust chemical prices provides an appropriate means to adjust older chemical prices to the present. In this study, PPIs were used to adjust four chemical prices over a 15-year period and assessed the results in terms of comparing to reported prices. The approach was moderately successful in that 90% of the PPI-adjusted prices were within ±50% of reported values and 81% were within a 2003-2018 historical price range for the chemicals studied. In addition to the comparisons of PPI-adjusted prices to reported values, this paper offers a few items to consider if planning to use PPIs to adjust chemical prices.

References

1. Couper, J.R., 2003, Process Engineering Economics, CRC Press, Boca Raton.
2. Garrett, D.E., 1989, Chemical Engineering Economics, Van Nostrand Reinhold, New York.
3. Anonymous, 2006, “Ammonia,” Chemical Week, Vol. 168, No. 29, p. 43.
4. Anonymous, 2008, “CW Price Report,” Chemical Week, Vol. 170, No. 37, p. 26.
5. Hubbard, D.E., 2018, “Chemical Pricing Information for Student Design Projects and Cost Engineering: Challenges and Opportunities,” Proceedings of the Annual ASEE Conference Proceedings, Salt Lake City, Utah June 24-27, 2018, pp. 1-18.
6. Cornell University Libraries, 2020, CHEME 4620/4630: Chemical Process Design: Prices & Suppliers. Available from https://guides.library.cornell.edu/c.php?g=1100119&p=8022887
7. Texas A&M University Libraries, 2020, Bulk Chemical Prices. Available from https://tamu.libguides.com/c.php?g=587308&p=4076262
8. University of Texas Libraries, 2020, Chemical Industry & Business. Available from https://guides.lib.utexas.edu/chemicalengineering/econ

9. U.S. Bureau of Labor Statistics. (2015). Chapter 14 - Producer Price Indexes. In BLS Handbook of Methods. Washington, D.C.: Government Printing Office. Available from https://www.bls.gov/opub/hom/pdf/ppi-20111028.pdf
10. U.S. Bureau of Labor Statistics (2018). Producer Price Indexes – Program Overview. Available from https://www.bls.gov/ppi/ppiover.htm
11. El-Halwagi, M.M, 2017, Sustainable Design Through Process Integration: Fundamentals and Applications to Industrial Pollution Prevention, Resource Conservation, and Profitability Enhancement, 2nd ed., Elsevier: Amsterdam.
12. Peters, M.S., Timmerhaus, K.D., West, R.E, 2003, Plant design and Economics for Chemical Engineers, 5th ed., McGraw-Hill, New York.
13. U.S. Bureau of Labor Statistics, Personal Communication, January 29, 2018.
14. Brown, T., 2007, Engineering Economics and Economic Design for Process Engineers, CRC Press, Boca Raton.
15. Han, J., 2017, "Process Design and Techno-Economic Evaluation for Catalytic Production of Cellulosic γ-Valerolactone using Lignin Derived Propyl Guaiacol, Journal of Industrial and Engineering Chemistry, Vol. 52, pp. 218-223.
16. Jiang, X., Abbati de Assis, C., Kollman, M., Sun, R., Jameel, H., Chang, H.-M., Gonzalez, R., 2020, "Lignin Fractionation from Laboratory to Commercialization: Chemistry, Scalability and Techno-Economic Analysis," Green Chemistry, Vol. 22, No. 21, pp. 7448-7459.
17. Mohan, G., Venkataraman, M., Gomez-Vidal, J., Coventry, J., 2018, "Thermo-Economic Analysis of High-Temperature Sensible Thermal Storage with Different Ternary Eutectic Alkali and Alkaline Earth Metal Chlorides," Solar Energy, Vol. 176, pp. 350-357.
18. Pham, V., El-Halwagi, M., 2012, "Process Synthesis and Optimization of Biorefinery Configurations," AIChE Journal, Vol. 58, No. 4, pp.1212-1221.
19. Wilson, A.N., Dutta, A., Black, B.A., Mukarakate, C., Magrini, K., Schaidle, J.A., Michener, W.E., Beckham, G.T., Nimlos, M.R., 2019, "Valorization of Aqueous Waste Streams from Thermochemical Biorefineries," Green Chemistry, Vol. 21, No. 15, pp. 4217-4230.
20. U. S. Geological Survey, Personal Communication, December 1, 2020.

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Appendix A. Selected Texts with Chemical Process Economics Information

Source[1]	PPI [2]	Notes
Brennan, D. (2013)	No	Chapter 3 Capital Cost Estimation (pp. 53-93) and Chapter 4 Operating Cost Estimation (pp. 95-125). States that the Consumer Price Index (CPI) is inappropriate for updating operating cost data (p. 120), though makes no mention of PPIs or other cost indexes that might be used to adjust such costs. Mentions a “materials price index” [a PPI] from the Australian Bureau of Statistics as part of a composite plant cost index (p. 65).
Brown, T. (2007)	Yes	Chapter 2 Time Value of Money (pp. 21-41). Pages 36-37 demonstrate adjusting an older chemical price using a PPI.
Couper, J.R. (2003)	No	Chapter 5 Estimation of Operating Expenses (pp. 125-152). Discusses and shows the Nelson-Farrar cost index used to adjust “chemical costs.” (p. 145). NOTE: The *Oil & Gas Journal* ceased publishing the Nelson-Farrar cost indexes in 2017, which is now available through subscription from BakerRisk https://www.bakerrisk.com/products/nelson-farrar-cost-index/
El- Halwagi, M. (2017)	Yes	Chapter 2 Overview of Process Economics (pp. 15-71) and Chapter 20 Macroscopic Approaches of Process Integration (pp. 533-565). Page 41 mentions the PPI and on page 553 the PPI is used to adjust chemical prices to compare pathways from different studies.
Garrett, D.E. (1989)	No	Chapter 4 Manufacturing Costs (pp. 41-66). Page 46 discusses raw materials and prices. A “Producers’ Price Index” is shown in a table on page 109, but in the context of the overall chemical economy and not for adjusting chemical prices.
Couper, J.R., Hertz, D.W., Smith, F.L. (2019)	No	Chapter 9 Process Economics (pp. 9.0-9.9). Section 9.4 Manufacturing/ Operating Expenses.
Happel, J. Jordan, D.G. (1975)	No	Chapter 5 Notes on Cost Estimation (pp. 213-258). The Wholesale Price Index (predecessor to the PPI) is mentioned in terms of an inflation indicator in the context of equipment (pp. 216-218).
Peters, M.S., Timmerhaus, K.D., West, R.E (2003)	No	Chapter 6 Analysis of Cost Estimation (pp. 226-278). There is a discussion of cost indexes (pp. 236-239) that states that cost indexes for raw materials exist and mentions the BLS though does not specify the PPI or any other price indexes for chemical prices by name.
Silla, H. (2003)	No	Chapter 2 Production and Capital Cost Estimation (pp. 29-146). Discusses raw material costs pp. 36-37. While acknowledging that “prices tend to be high,” author suggests using laboratory suppliers Sigma-Aldrich, Alfa Aesar and Fisher Scientific for chemical price data which is ill-advised. The author does state that the most accurate source is the *Chemical Market Reporter* (now *ICIS Chemical Business*).
Towler, G., Sinnott, R. (2013)	No	Chapter 8 Estimating Revenues and Production Costs (pp. 355-387). Several methods of forecasting chemical prices were presented (pp. 367-370), but none of those methods mentioned using PPI or other price indexes to adjust older chemical prices.

[1] Complete citations are listed below.
[2] PPI mentioned or used in the context of chemical price adjustments.

Appendix A. Selected Texts (Continued)

Brennan, D., 2013, Process Industry Economics: Principles, Concepts and Applications, 2nd ed., Elsevier, Amsterdam.

Brown, T., 2007, Engineering Economics and Economic Design for Process Engineers, CRC Press, Boca Raton.

Couper, J.R., 2003, Process Engineering Economics, CRC Press, Boca Raton.

Couper, J.R., Hertz, D.W., & Smith, F.L., 2019, "Section 9: Process Economics," in Perry's Chemical Engineers' Handbook, D.W. Green and M.Z. Southard, Eds., 9th ed., McGraw-Hill, New York.

El-Halwagi, M.M, 2017, Sustainable Design Through Process Integration: Fundamentals and Applications to Industrial Pollution Prevention, Resource Conservation, and Profitability Enhancement, 2nd ed., Elsevier, Amsterdam.

Garrett, D.E., 1989, Chemical Engineering Economics, Van Nostrand Reihold, New York.

Happel, J., Jordan, D.G., 1975, Chemical Process Economics, 2nd ed., Marcel Dekker, New York.

Peters, M.S., Timmerhaus, K.D., West, R.E, 2003, Plant design and Economics for Chemical Engineers, 5th ed., McGraw-Hill, New York.

Silla, H., 2003, Chemical Process Engineering: Design and Economics, Marcel Dekker, New York.

Towler, G., Sinnott, R., 2013, Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design, 2nd ed., Elsevier, Amsterdam.

Appendix B. Reported and Adjusted Prices for Ammonia, Ethylene, Soda Ash, and Styrene
NOTE: Abbreviations used in figures and tables for PPIs are listed at the end of this appendix.

Figure 5. Reported and PPI-Adjusted Prices for Ammonia

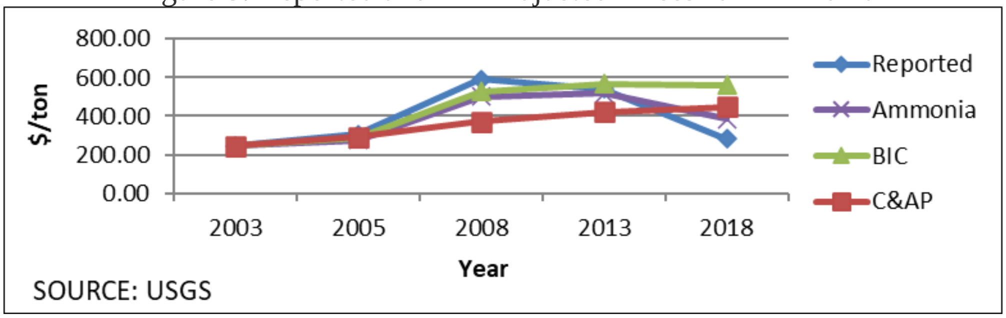

Table 2. Percent Differences for Reported Versus PPI-Adjusted Prices for Ammonia

Year	Ammonia	BIC	C&AP
2003	NA	NA	NA
2005	10%	6%	4%
2008	15%	10%	37%
2013	4%	5%	22%
2018	36%	99%	59%
Avg	16%	30%	31%
Hi	36%	99%	59%
Low	4%	5%	4%
Annualized	4%	9%	5%

Figure 6. Reported and PPI-Adjusted Prices for Ethylene

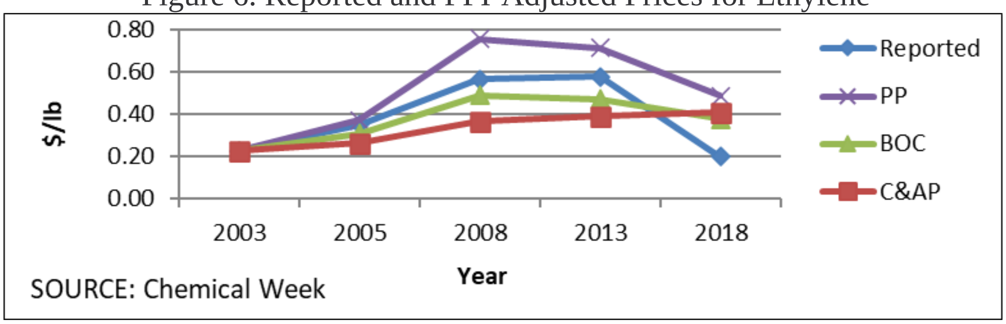

Table 3. Percent Differences for Reported Versus PPI-Adjusted Prices for Ethylene

Year	PP	BOC	C&AP
2003	NA	NA	NA
2005	6%	12%	25%
2008	33%	14%	35%
2013	24%	18%	33%
2018	143%	89%	104%
Avg	69%	44%	65%
Hi	143%	89%	104%
Low	6%	12%	25%
Annualized	8%	4%	5%

Figure 7. Reported and PPI-Adjusted Prices for Soda Ash

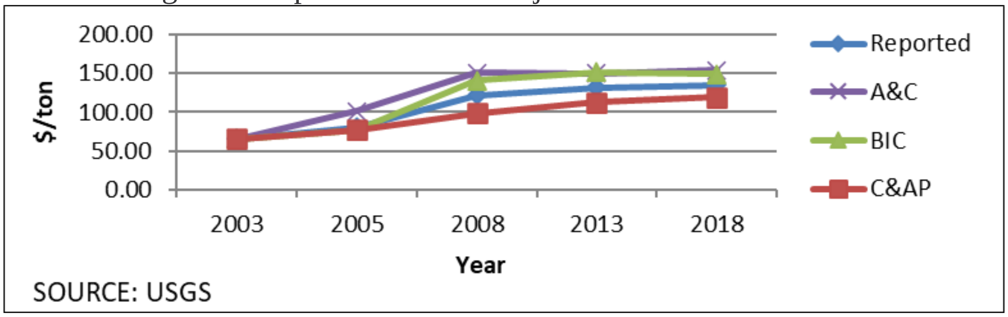

Table 4. Percent Differences for Reported Versus PPI-Adjusted Prices for Soda Ash

Year	A&C	BIC	C&AP
2003	NA	NA	NA
2005	26%	5%	4%
2008	24%	15%	19%
2013	14%	15%	15%
2018	14%	11%	12%
Avg	19%	11%	12%
Hi	26%	15%	19%
Low	14%	5%	4%
Annualized	9%	9%	5%

Figure 8. Reported and PPI-Adjusted Prices for Styrene

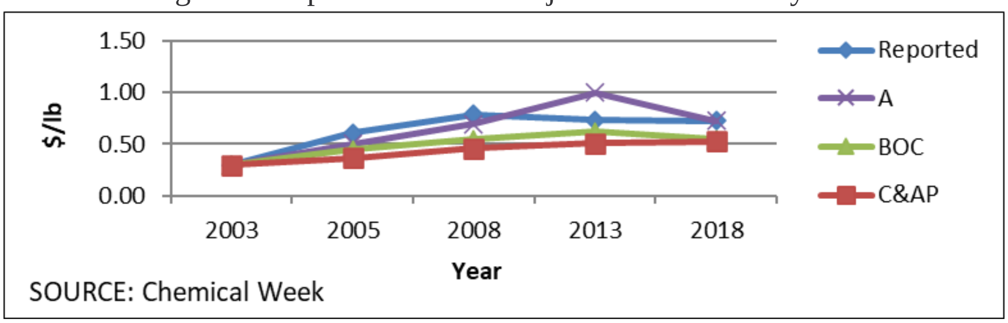

Table 5. Percent Differences for Reported Versus PPI-Adjusted Prices for Styrene

Year	A	BOC	C&AP
2003	NA	NA	NA
2005	18%	27%	40%
2008	12%	31%	42%
2013	37%	15%	30%
2018	0%	24%	27%
Avg	17%	24%	35%
Hi	37%	31%	42%
Low	0%	15%	27%
Annualized	10%	6%	5%

<u>Abbreviations for the PPIs Used in the Appendix B Figures and Tables</u>
A - Chemicals and Allied Products: Aromatics (WPU06140197)
A&C - Chemicals and Allied Products: Alkalies and Chlorine…(WPU061303)
Ammonia - Chemicals and Allied Products: Synthetic Ammonia…(WPU0652013A5 and 652013A)
BIC - Chemicals and Allied Products: Basic Inorganic Chemicals (WPU0613)
BOC - Chemicals and Allied Products: Basic Organic Chemicals (WPU0614)
C&AP - Chemicals and Allied Products (WPU06)
PP - Petroleum Refineries: Primary Products (PCU324110324110P)

<u>Data Sources</u>
Ammonia
United States Geological Survey, 2020, Mineral Commodity Summaries: Nitrogen (Fixed) – Ammonia. U.S. Geological Survey, Reston. [Used 2008, 2011, 2014, 2017, and 2020 editions].

Ethylene
Anonymous, 2003, "CW Price Report," Chemical Week, Vol 165, No. 15, p. 26.

Anonymous, 2005, "CW Price Report," Chemical Week, Vol. 167, No. 12, p. 37.

Anonymous, 2008, "CW Price Report." Chemical Week, Vol. 170, No. 29, p. 43

Boswell, C., 2013, "Feeds, End Markets Determine Outlook for US Olefin, Aromatics, Chemical Week," Vol. 175, No. 19, p. 26.

Anonymous, 2018, March 12, "US Ethylene Process Continue to Fall Amid Extreme Length," Chemical Week, Vol. 180, No. 7, p. 5.

Soda Ash
United States Geological Survey, 2020, Mineral Commodity Summaries: Soda Ash. U.S. Geological Survey, Reston. [Used 2008, 2011, 2014, 2017, and 2020 editions].

Styrene
Anonymous, 2003, "CW Price Report," Chemical Week, Vol.165, No. 35, p. 28.

Anonymous, 2005, "CW Price Report," Chemical Week, Vol.167, No. 36, p. 26.

Anonymous, 2008, "CW Price Report," Chemical Week, Vol.170, No. 31, p. 47.

Boswell, C., 2014, "IHS: Styrene Margins to Narrow in 2014, but Long-Term Outlook Positive, Chemical Week, Vol. 176, No. 2, p. 27.

Boswell, C. "Styrene Surges on Cosmar Outage," Chemical Week, Vol. 180, No. 3. P. 27.

Producer Price Indexes
PPI data related to chemicals is available online from the Federal Reserve Bank of St. Louis at the following website: https://fred.stlouisfed.org/release/tables?rid=46&eid=142872