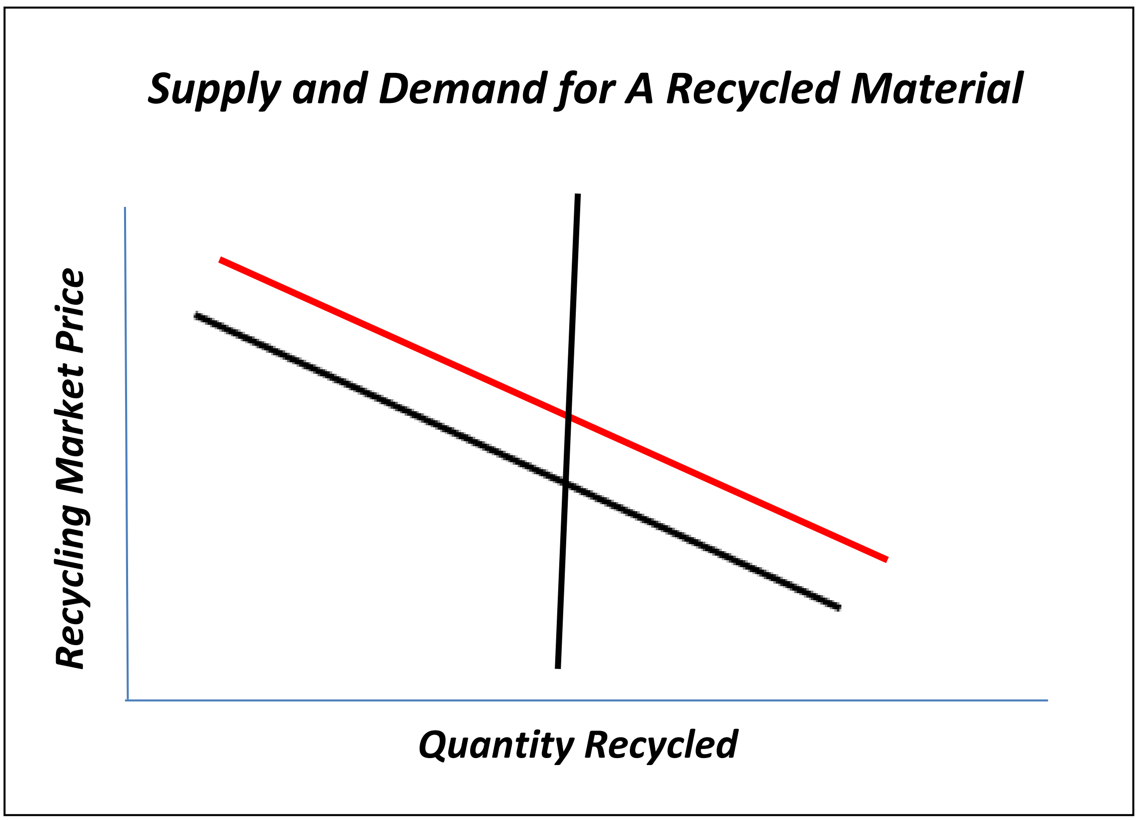
Oregon Recycling Markets Price Cycles and Trends: A Statistical Search for Significant Economic Causes

Prepared for the State of Oregon
Department of Environmental Quality

October, 2016



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Contents

Introduction

The Oregon Department of Environmental Quality (DEQ) contracted with Sound Resource Management Group, Inc. (SRMG) to gather Oregon recycling markets price data and analyze those data to answer two main questions:

- What are the primary causes of recycling market price fluctuations and trends for eight commonly recycled materials -- newspaper, cardboard, mixed paper, aluminum cans, tin cans, polyethylene terephthalate (PET) bottles, high-density polyethylene (HDPE) containers, and glass containers?
- Have these causes changed recently?

Four recycling market participants in Oregon: two material recovery facilities (MRFs) – Far West Recycling and KB Recycling, one hauler -- Rogue Disposal, and one governmental agency -- Lane County, agreed to provide price data, some assembled with considerable effort on their part.

These Oregon recycling entities access markets at different points in the recycling supply chain. That supply chain extends from home or business to collector to processor to marketer to end-use manufacturer of recycled-content products. Pricing levels are different for any given recycled material at different points in this supply chain, just as wholesale and retail price levels are different for any given consumer good. Prices may also differ if varying combinations of commingled materials are sold as a single "commodity", or if higher transportation costs are incurred due to greater shipping distances to processors or end-use markets. For these reasons, grouping together Oregon prices reported by different entities from different points in the supply chain could create anomalies that would confound or bias answers to the study questions.

Also problematic was that none could provide pricing data that included the substantial recycling market price spikes in 1994-95 and 1999-2000, the dramatic price declines at the end of 2008, and the pricing recovery peaks during the 2009-2012 price cycles. Data covering cycles both before and after the 2008 financial crisis would seem to be required to adequately answer this study's two main questions.

A possible solution was to see how closely Oregon price data correlate with other regional end market pricing data. Fortunately, SRMG maintains a nearly 30-year long dataset of publicly available end-user recycling market prices reported by companies contracted to collect, process and market recyclables from Puget Sound, Washington area cities. As shown in Table 3 in the Methods section of this report, prices in the SRMG dataset are highly correlated with Oregon prices during months included in the Oregon datasets. Although high correlations do not imply that Oregon and Puget Sound price levels are the same, they do mean that Puget Sound and Oregon recycling market pricing trends and fluctuations are nearly identical.

This suggests that statistical calculations and modeling necessary to answer this study's questions can be based on SRMG's Puget Sound pricing data. Hence, these are the recycling markets pricing data on which SRMG carried out the analysis and reached the conclusions discussed in this report.

The one exception was that there were no significant correlations between Puget Sound and Oregon recycled glass market prices for the limited data sequences on glass market prices provided by Oregon recyclers. However, one Oregon recycling participant did provide data for January 2011 thru June 2016 that was sufficient for answering the first study question for recycled glass prices during these recent 66 months.

Summary & Conclusions

Recycling market prices in Oregon (as elsewhere) have fluctuated widely, and at times wildly, over the past 25 years, as illustrated by the graphs in the Results section of this report. Yet real price levels, measured on a constant 2009 dollar basis, do not seem to be trending dramatically up or down.[1]

Table 1 indicates that long-run pricing trends for recycled materials, other than glass[2], range between a downtrend of $0.10 per month for aluminum cans to an uptrend of $0.51 per month for high density polyethylene (HDPE) containers. Since November-December 2008, recycled materials, other than cardboard, have yielded higher, some materials dramatically higher, prices on average compared with price averages prior to that time. However, since the financial crisis, monthly prices on average trended down through 2015, other than for aluminum cans and HDPE containers. The data in Table 1, of course, cannot answer the question of what current trends indicate for the future, that is, whether post-crisis downtrends portend permanent slumps or are instead temporary phenomena. Prices for the first six months of 2016 are trending up or mixed, but not down.

Table 1
Recycling Market Price Trends

Recycled Material	Number of Years of Price Data	Average Price Over All Years	Pre-2008 Crisis Average Price	Post-2008 Crisis Average Price	Monthly Trend Over All Years	Monthly Trend Since 2008 Crisis	Monthly Trend Since Last Cycle Bottom	Overall Trend 1st 6 Months 2016	Different Price Drivers Post 2008 Crisis
		Real Prices per Ton (2009$)							
Newspaper	28.5	$86	$80	$102	$0.20	-$0.40	-$0.51	up	yes
Cardboard	23.5	$125	$128	$121	-$0.04	-$0.81	-$0.83	mixed	yes
Mixed Paper	28.5	$66	$58	$90	$0.29	-$0.70	-$0.80	up	no
Alum. Cans	28.5	$1,068	$1,065	$1,077	-$0.10	$1.35	$10.50	mixed	yes
Tins Cans	28.5	$87	$49	$117	$0.27	-$0.96	$0.32	mixed	yes
PET Bottles	22.5	$327	$303	$390	$0.46	-$7.21	-$1.89	up	yes
HDPE Containers	23.5	$369	$313	$480	$0.51	$0.72	$0.20	up	yes
		Glass Prices Index (1st 6 months 2016 = 100)							
Glass Containers	5.5	39.6	NA	39.6	3.3	NA	NA	flat	NA

NA = Not Applicable.

[1] All recycling prices exhibited or discussed in this report, unless stated otherwise, are adjusted to a 2009 constant dollar basis in order to eliminate price changes related to inflation. The year 2009 is used as the base for deflating prices because the U.S. Bureau of Economic Analysis (BEA) uses 2009 as the base year for quantity indexes of industry gross output. Choice of 2009 as the base year for price indexing is consistent with BEA's choice, but serves no other purpose. Choosing a different base year for indexing prices would not affect any results reported herein.
[2] This discussion excludes recycled glass because long-term pricing data were not available to characterize glass recycling cycles and trends for Oregon. Recycled glass prices available and analyzed for this study are for January 2011 through June 2016 only.

The last column of Table 1 indicates a positive answer to the question of whether the causes and drivers of market price cycles and trends have changed in recent years for each recycled material other than mixed paper and glass. The 2008 financial crisis provided the break point for examining this question. This is an appropriate demarcation because recycling prices reached historic or near-historic lows in late 2008 and there are complete price cycles both before and after that time for all recycled materials other than glass containers.

Table 2 lists economic variables that significantly influenced recycling markets in the time periods before and after the 2008 financial crisis.[3] A "yes/yes" in the table indicates that an economic factor had a significant impact both before and after the crisis. A "yes/no" and a "no/yes" entry for an economic variable indicate, respectively, that the variable was significant before, but not after the 2008 crisis, and vice versa. The hyphen (-) means "does not apply".

Table 2
Statistically Significant Economic Variables Affecting Prices for Recycled materials

Statistically Significant Economic Variables	Newspaper	Cardboard	Mixed Paper	Aluminum Cans	Tin Cans	PET Bottles	HDPE Containers	Glass Containers
	yes = significant pre-crisis/yes = significant post-crisis							
Industry Output	yes/yes	yes/yes	no	yes/yes	no/yes	yes/yes	yes/yes	-/yes
Capacity Utilization	no/no	no/no	no	no/no	yes/yes	yes/yes	yes/yes	-/no
U.S. Recycling Quantity	yes/yes	no/yes	no	no/no	no/no	no/no	no/no	-/no
Crude Oil Price	yes/no	yes/yes	yes	no/no	yes/yes	no/yes	no/yes	-/yes
U.S. Industrial Electricity Price	yes/yes	no/no	yes	no/yes	no/no	no/no	no/no	-/yes
U.S. Average Wage Rate	yes/yes	yes/yes	yes	no/no	yes/yes	no/no	yes/no	-/yes
U.S. Recession Months	no/no	yes/yes	no	no/no	no/no	no/no	no/no	-/-
West Coast Port Labor Slowdowns	no/no	no/no	no	yes/yes	yes/no	yes/no	yes/no	-/no
Export Spike Pre-2014-15 Slowdown	-/no	-/no	no	-/yes	-/yes	-/no	-/yes	-/no
U.S. $ Foreign Exchange Rate	no/yes	no/no	no	yes/no	no/no	no/no	no/no	-/no
China's Green Fence	-/no	-/no	yes	-/no	-/no	-/yes	-/no	-/no
China's Real GDP Growth	yes/yes	no/yes	no	no/yes	no/yes	no/yes	no/yes	-/no
India's Real GDP Growth	no/no	no/no	yes	no/no	no/no	yes/no	no/no	-/no
Seasonality	yes/yes	no/yes	yes	no/yes	no/yes	no/yes	no/yes	-/no

Other noteworthy explanatory items for Table 2:

- Mixed paper has only single word entries in its column. This is because economic drivers for mixed paper prices have not changed significantly from before to after the 2008 financial crisis.
- Some variables relate only to post-financial crisis months. Data for Oregon recycled glass price fluctuations were only available for the post-crisis years beginning 2011. China's Operation Green Fence beginning in 2013 and the export quantity spikes for several

[3] Among economic variables examined in this study were several that were insignificant for explaining recycling price cycles and trends. These included U.S. natural gas prices for industrial users, U. S. gross domestic product (GDP) and its growth rate, and export quantities for various paper/paperboard recycled commodities. Of course there are numerous economic variables not examined in this study – various measures of the money supply, government spending and interest rates, to name a few. One or more of these left out variables could be important for explaining recycling market price fluctuations. Yet, variables that were analyzed cover all the important factors that economic theory and literature on recycling markets suggest impact recycling prices.

recycled materials just prior to the 2014-2015 West Coast ports labor slowdown apply only during post-financial crisis months. Hence the non-applicable pre-crisis period for those two variables, as well as for glass, are designated by a hyphen amongst the entries in the Table 2 columns.

Table 2 entries, as well as the discussion of estimates for influences of each economic factor for each material provided in the Results section of this report, suggest the following conclusions:

- Higher levels of newspaper or cardboard recycling in the U.S. have very small (pennies per thousand tons of additional recycling) negative impacts on prices for these recycled commodities. Recycling rates for other U.S. generated materials had no significant influence on market prices. These results indicate that U.S. recycling levels have very minor influences on market prices. This may be surprising given that a negative association is what one might expect for the relationship between quantity recycled and recycling market price, as discussed in the Results section under conceptual economic modeling. However, the influence that international recycling levels and market prices have on U.S. recycling prices likely moderate and substantially overwhelm any price level influence from recycling quantities in just the U.S.
- Pricing drivers for materials other than mixed paper in the Puget Sound pricing dataset changed significantly after the 2008 financial crisis. For example, crude oil prices had a significant influence on PET and HDPE prices post-crisis, but not pre-crisis. Vice versa for newspaper prices.
- In either pre- or post-financial-crisis months, or both, higher crude oil prices are associated with higher recycling market prices for all materials (including glass) other than aluminum cans; lower crude prices with lower recycling prices. For example, a drop from $100 to $50 per barrel would yield a post-crisis price decrease per ton recycled of $30 for cardboard, $47 for mixed paper, $46 for tin cans, $151 for PET, $148 for HDPE and $0.50 for glass. Such a drop pre-crisis would yield a decrease of $67 per ton for newspaper. This association between prices for crude oil and recycled materials is likely explained by the fact that crude oil prices serve as a surrogate for overall energy costs. Studies typically show that manufacturing products from recycled materials is less energy intensive than using virgin raw materials. For this reason manufacturers would be motivated to use more recycled content when energy costs go up, as indicated by rising crude oil prices, and less when crude oil prices fall.
- Output levels for an industry that uses a specific recycled material for manufacturing products have significant and usually positive impacts on that material's market price. Only mixed paper showed no significant relationship between industry output and market price. Tin cans also showed no significant impact for industry output, but only during months in the pre-crisis years.
- Capacity utilization has a significant influence only on market prices for tin cans, PET and HDPE. Correlation between output and capacity utilization may tend to confound estimation of their separate impacts on recycling prices. Collinear cycles and trends in output and

capacity utilization levels may also explain the significant, but unexpectedly negative price impacts from higher output levels for end-use industries manufacturing products from recycled PET or recycled HDPE.

- Cardboard is the only material showing negative price impacts during recession months that were separate from, and in addition, price impacts from falling recycled-content manufacturing output. Other materials showed negative price impacts from falling output and/or lower utilization of manufacturing capacity, which often occur during recessionary periods. But other materials but did not exhibit such additional negative price impacts during months of U.S. economic recession.
- Variables influencing export market demand – growth rates for real gross domestic product (GDP) in China or India, or the foreign exchange value of the U.S. dollar – impact prices for all recycled materials except glass. Given that it is seldom cost-effective to ship recycled glass cullet to overseas markets due to its low market value, the non-significance of export markets for glass is not surprising. The other notable exception for export demand effects is that prior to the financial crisis none of the variables reflecting export demand conditions had a significant influence on market prices for recycled cardboard. This likely reflects the fact that cardboard exports absorbed less than 10% of U.S. cardboard recycling quantity in 1999 and only 17% in 2004, versus 28% in 2009 and more than 32% in 2015.
- Implementation of China's Green Fence beginning February 2013 had a significant impact only on prices for mixed paper and PET.
- Labor slowdowns both before and after the financial crisis at West Coast ports have impacted prices for recycled metals and plastics, but not paper and cardboard.
- Prices for all recycled materials other than glass exhibit significant seasonal swings.

In sum, the economic factors that influence recycling market prices and the magnitude of the impacts of these factors have changed since the 2008 financial crisis. Output of industries able to manufacture recycled-content products, crude oil prices, export markets, and seasonal demand fluctuations exerted significant influences on market prices for most recycled materials during months since the financial crisis. Many of these same variables were influential before the crisis; but their impacts, in general, have broadened across more recycled materials and strengthened in intensity since 2008.

For example, since the financial crisis the quarterly rate of growth in China's GDP has a significant impact on prices for all recycled materials other than mixed paper and glass, as indicated in Table 2. The slowdown in that growth rate from an average of 2.5% during 2000 through 2011 to 1.8% during 2012 through 2015 yields a drop in average market prices for a ton of recycled material of $24 for newspaper, $19 for cardboard, $143 for aluminum cans, $13 for tin cans, $66 for PET bottles, and $36 for HDPE containers. In addition, China's Operation Green Fence caused a drop of $16 per ton for mixed paper and $121 per ton for PET bottles.

It is still too early to determine whether recycling markets will fully recover from their recent downturns and continue to yield the higher real prices on average that they have in the months since

2008 compared with average prices prior to the 2008 financial crash. Price trends during the first six months of 2016 provide an optimistic note on that score.

There are several avenues that may be useful for further research. One would be to develop an index or some other measure of the degree to which each material was collected from homes and businesses separately versus commingled with other materials. There are studies showing higher rates of non-recyclables in commingled collection containers and higher rates of outthrows and prohibitives in materials marketed to end-users from material recovery facilities (MRFs) processing commingled materials. On this basis one would expect a negative association between commingling and recycling prices. SRMG was unable to find a measure of collection commingling for use in the analysis reported herein.

It is also possible that there are lags in the effects of some economic variables on recycling prices. For example, industry output or capacity utilization may go up or down a month or more before recycling prices move up or down. There was insufficient time and budget to investigate the existence of lagging price responses to one or more of the economic drivers identified in the current study.

Methods

This section discusses recycled materials market pricing data, the conceptual economic model for analyzing cycles and trends in market prices, and the statistical models used to identify and quantify economic factors driving those cycles and trends.

Pricing Data

SRMG, with advice and assistance from DEQ staff, City of Portland staff and others, reached out to Oregon recyclers to request pricing data for Oregon. This effort yielded data from four recycling market participants in Oregon: two material recovery facilities (MRFs) – Far West Recycling and KB Recycling, one hauler -- Rogue Disposal, and one governmental agency -- Lane County. These four sources provided what data they could gather.

These data sets were insufficient overall to adequately answer this study's two questions. There are two main reasons for the data shortcomings:

1. No single entity provided monthly pricing data for years that included the substantial spikes in 1994-95 and 1999-2000 as well as the dramatic price declines in 2008. Reasonably accurate answers to this study's two questions require prices from the substantial cyclical fluctuations that occurred both before and after the 2008 financial crisis.
2. The four Oregon recycling markets participants access markets at different points in the recycling supply chain. This supply chain extends from home or business to collector to processor to marketer to end-use manufacturer of recycled-content products. The MRFs likely sell to end-use manufacturers. Rogue Disposal probably sells to MRFs or broker/marketers. Lane County may sell to MRFs, brokers, or even end-users. Price levels at different points in this supply chain are different, just as wholesale and retail prices for a consumer good are typically different. Hence, grouping together prices gathered at different

points in this supply chain in order to create a price series that covers major fluctuations occurring on both sides of the financial crisis likely would create price level anomalies when prices jump from one point in the supply chain to another. This could confound or bias the study's estimates and conclusions.

SRMG maintains a long-term dataset of publicly available end-user recycling market price data reported by companies contracted for collection, processing and marketing of recyclables in Puget Sound area cities. To determine whether these pricing data would be a viable substitute for actual data on Oregon prices, SRMG correlated those Puget Sound Prices with prices reported by the four Oregon recyclers. Table 3 shows the resultant correlations. The correlations are quite high – ranging above 0.9 in one or more dataset for all materials listed in the table. One exception was that correlation between Oregon and Puget Sound glass prices was not significantly different from zero.

High correlations do not imply that Oregon and Puget Sound price levels are identical. However, they do mean that the Puget Sound area price trends and fluctuations are nearly identical to trends and fluctuations exhibited in the data collected from Oregon entities. This study is designed to examine pricing trends and cycles over time, so the statistical evaluations and modeling carried out for this study are based on the Puget Sound data, except for glass containers.

The Puget Sound monthly pricing data represent average monthly revenues ("average prices") received by MRFs from end-use manufacturers for recycled materials processed, packaged to recycled materials market specifications, and shipped to end users. These average prices reflect FOB (free on board) amounts paid to MRFs, where FOB means that end users pay shipping costs. Newspaper, mixed paper, aluminum can and tin can price series go back to February 1988. For cardboard and HDPE monthly data go back to January 1993. PET prices go back to January 1994. Pricing data for these seven materials were sufficient to answer both study questions.

Table 3

Correlations between Oregon and Washington Puget Sound Area Recycling Market Prices

Oregon Data Availability Periods	Correlation Coefficients for Oregon-Puget Sound Prices for Indicated Recycled Materials								
	ONP	OCC	Mixed Paper	Aluminum Cans	Tin Cans	PET	HDPE-Mixed	HDPE-Natural	HDPE-Colored
01/2002 thru 12/2002		0.95			0.49		0.70		
01/2010 thru 06/2011		0.91							
12/2014 thru 05/2016						0.76		0.93	0.50
01/2014 thru 06/2016	0.68	0.85		0.92	0.77, 0.92			0.89	
01/2011 thru 06/2016	0.94	0.95	0.90	0.34	0.58	0.90		0.85	
01/2006 thru 06/2016	0.90	0.91							

For glass containers, one Oregon recycling market participant provided data for January 2011 through June 2016. These data are sufficient to answer the first, but not the second, study question. Oregon glass recycling prices are displayed in the chart in the Results section as index numbers with the average for the first 6 months of 2016 set equal to 100. This convention is used to avoid disclosing actual price levels provided by the Oregon entity. Indexing provides information for the study without revealing anything about actual price levels obtained by Oregon recycling market participants.

The final note regarding recycling market prices used to analyze trends, cycles, and price level determinants is that all pricing data were deflated to constant 2009 dollars.[4] This adjustment was done for each recycled material based on the producer price index (PPI) for an industry or product that uses that recycled material as a feedstock to manufacture recycled-content products:

- Newspaper prices were deflated by the PPI for newsprint.
- Cardboard prices were deflated by the PPI for paperboard products.
- Mixed paper prices were deflated by the PPI for paper products.
- Aluminum can prices were deflated by the PPI for aluminum sheet metal.
- Tin can prices were deflated by the PPI for iron and steel mill products.
- PET bottle prices were deflated by the PPI for synthetic fibers.
- HDPE container prices were deflated by the PPI for plastic bottles.
- Mixed color glass prices were deflated by the PPI for glass containers.

The reasoning behind deflating prices by an index specific to an industry that uses a particular recycled material to manufacture recycled content products is that the real value (i.e., inflation-adjusted price) of that recycled material is likely to be closely related to the real value of the product(s) manufactured using that particular material. Inflation in recycled material prices, thus, can be adjusted out more accurately using the appropriate PPI for recycled-content product(s) rather than one of the consumer price index (CPI) measures for general price changes in consumer goods.

The Conceptual Economic Model

There's an old saying that it's easy to train a new economist. Just teach a parrot to say "Supply and demand." It's a good joke, yet the supply of a recycled material and the demand for its use in manufacturing products do interact with each other to produce the prices we observe over time for that particular recycled material. The conceptual and statistical problem is sorting out which factors affect demand and which affect supply to determine those observed market prices.

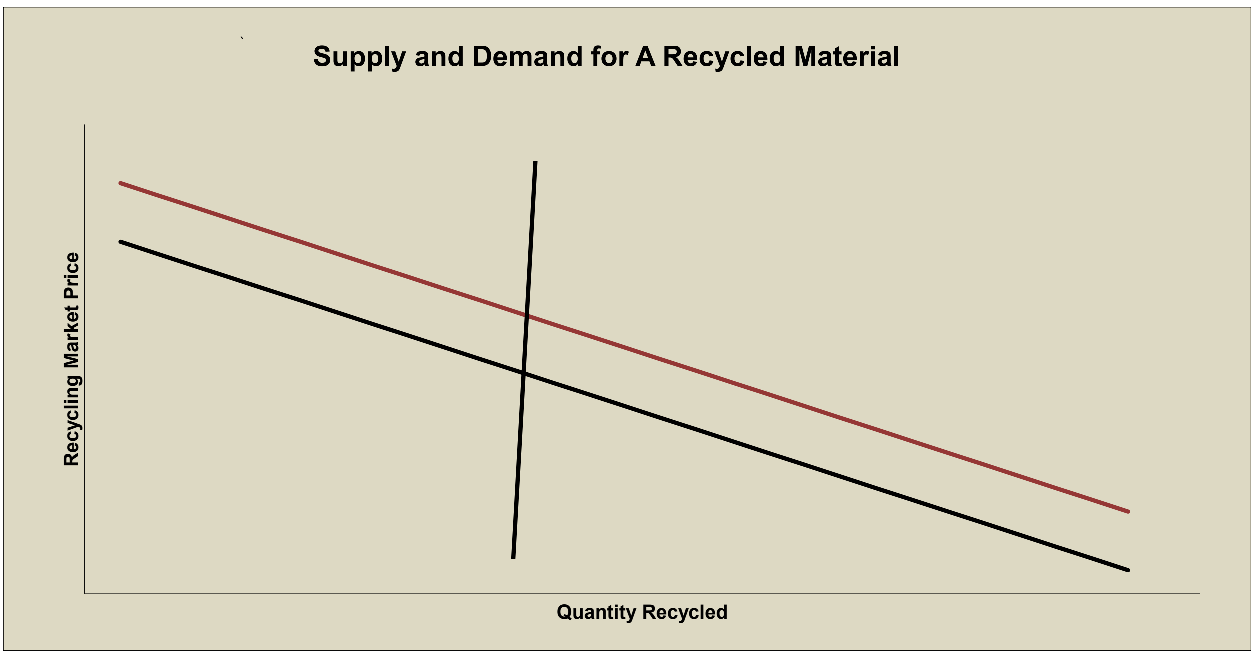
Fortunately, the sorting out problem may be less difficult here due to the fact that municipal collection programs for recyclables, more often than not, are set up to collect recyclables month in and month out regardless of what price those collected materials will bring once they have been processed and packaged for shipment to end users. In addition, new collection programs are often instituted at the behest of political entities driven by social and environmental objectives rather than by private entities

[4] See footnote 1.

seeking to maximize the margin between price and collection/processing costs. Hence supply of a recycled material for sale on recycling markets is likely to be insensitive to market prices.

Figure 1 provides a conceptual model of just such a market. The nearly vertical curve on the graphic is the supply curve, representing the amount of a recycled material collected and processed in a month. Based on the assumption that recycling collections are motivated much more by social and environmental rather than economic considerations, monthly amounts collected and processed will not change much in the short run no matter what price end-use manufacturers might be willing to pay. Hence the supply curve does not show much increase in quantity recycled when prices are higher. Such a supply curve is deemed very inelastic – price increases don't stretch out quantity recycled much at all.

Figure 1



On the other hand (another favorite saying used by economists), the more horizontal curves on Figure 1 represent the amount end-users are willing to buy at various potential market prices for the recycled material. These are demand curves. As recycling market prices go down, end users are willing to buy more recycled material to use in manufacturing their products. When prices go up, end users will buy less recycled material. These demand curves are more elastic than the supply curve – i.e., changes in purchases by end users are much more stretched out as a result of price changes than is the case for changes in quantities recycled.

The red curve is shifted up to indicate that end users are willing to pay higher prices given some positive change in their situation. Examples of such changes are increased demand for the product(s) they are manufacturing, reduced real wages paid to their work force, and lower real prices for energy to power their production processes.

The price and quantity at which supply and demand curves intersect represent the price point at which end users and collectors/processors are both satisfied with the quantities they want to purchase and sell, respectively. What's important about the nearly vertical shape of the supply curve and the assumption that it takes a number of months before it shifts around much is that the observed monthly price changes during those months of relatively stable supply must be caused by shifts up or down in end user demand for recycled material.

The basic idea is that shifts up or down in demand identify pricing impacts of economic factors other than recycled material market prices that drive changes in end users' demand for a recycled material. This is the conceptual economic basis for the statistical models this study uses to estimate the causes or drivers of fluctuations over time in recycling market prices. In other words, changes on the demand side of recycling markets drive most of the cycles and trends we observe in recycling market prices.[5]

Statistical Modeling

SRMG used two different statistical models to identify and estimate the quantitative impact of factors that influence recycling market price cycles and trends.[6] The first, Model 1, is a statistical estimation procedure that is often used to separate out the individual impacts of multiple economic factors. Model 1 is used here to identify and provide separate estimates for the quantitative price impact of each demand side factor driving recycling price fluctuations and trends.

Model 1 also facilitates a straight forward test of the hypothesis that recycling markets changed after the 2008 financial crisis. That crisis was selected as the break point for testing separation in market characteristics because recycled materials, other than glass, all reached a deep bottom in their price cycles in November or December of 2008. These materials also experienced at least one price cycle upturn followed by a downturn after those 2008 pricing bottoms. This structuring of the test for whether recycling market price behavior is different in recent years seems appropriate because both pre- and post-financial crisis periods contain substantial price fluctuation and trending behaviors. The

[5] The 2008 financial crisis and the resultant Great Recession probably reduced consumer spending enough over time to cause municipal collection of recycled materials to decline during the recessionary months. This would be represented by a shift back toward zero for the nearly vertical supply curve in Figure 1. As a result, market prices for recyclable materials would rise if end-user demand for recyclables didn't decline at the same time. Sorting out such supply driven price increases from demand driven effects would require use of more complex econometric methods than were used for this study. The sharp decreases in recycling prices following the economic shocks from the 2008 financial crash indicate that price increasing impacts from reduced supply were overwhelmed by the price decreasing impacts of reduced demand. This suggests that the econometric techniques used for this study likely provide reasonably robust and unbiased estimates for the impacts of economic forces acting on the demand side of the markets for recycled materials. Supply side shifts are too slow and too weak to bias estimates of these demand side shifts calculated by the more simple econometric methods used for this study.

[6] For those familiar with econometric and/or statistical methods, Model 1 is the ordinary least squares method and Model 2 is the auto regressive method for calculating the impacts of multiple economic factors on recycling prices. SRMG used GRETL (Gnu Regression, Econometrics and Time-series Library) software to calculate coefficient estimates and evaluate their statistical significance. GRETL is an open-source software package for econometric analysis and is available at: http://gretl.sourceforge.net/ .

post-crisis period also includes the recent 3 to 4 years of slumps in prices for some materials that concern so many private and public sector participants in recycling markets.

The second model, Model 2, is a statistical estimation procedure that is often useful for predicting near term behavior in economic time series. It relies on the typically rhythmic movements in economic time series to predict future movements based mostly on recent observations. Prediction is not one of the objectives for this study. Yet including estimation results from Model 2 and showing how tightly Model 2 estimated values fit actual recycling market price movements, highlights one of the difficulties in separately identifying factors that impact recycling prices. That difficulty is that economic data of various kinds often tend to move similarly. Several economic factors, say recycled-content product output and energy prices, which might have important effects on recycling market prices, may move in a highly correlated relationship to each other over time. In these situations it is often difficult to statistically sort out their separate impacts on recycling prices. This can limit the power of Model 1 to closely explain and track recycling price cycles and trends.

Model 2 takes the point of view that observed cycles in recycling prices can be used to model the behavior of recycling markets due to those markets being inherently cyclical. Where Model 1 estimates to what extent certain economic factors drive current recycling prices; Model 2 estimates to what extent past recycling prices drive current recycling prices.

Model 2 also may find that some economic factors in addition to past recycling prices influence the current recycling price. However, in general for recycling prices under Model 2, fewer economic factors are identified as significant drivers once the influences of past recycling prices are accounted for. This is because economic factors also are reflected in the behavior of past prices, so their influence on the current recycling price is absorbed in, or modulated by, the estimate of the influence of past recycling prices. Another way of explaining this is that previous prices may explain so much of the variation in current prices that there is little variation left to be explained by some of the economic factors identified as important by Model 1.

SRMG used Model 2 as a fall back procedure for checking reasonableness of Model 1 estimates. This reasonableness test is in addition to the usual tests of statistical significance used to validate Model 1 selections of economic variables important for explaining recycling price cycles and trends.

Results

This section details the results from Models 1 and 2 for determinants of trends and fluctuations in recycling market prices.[7] Each of the eight recycled materials is discussed separately. In the discussion of results, it is important to remember that recycling prices are measured in constant 2009 dollars, i.e., they are real prices, unless the text notes that prices are nominal.

Before turning to those separate discussions, there are several general results that are worth noting.

[7] Data variables and sources are described and listed in the appendix.

- Recycling prices crashed to their financial crisis price bottoms within a span of just the last two months of 2008.
- For newspapers, cardboard, aluminum cans, tin cans, PET bottles and HDPE containers, the Model 1 factors explaining price fluctuations are different after the 2008 financial crisis than they were before. The quantitative influence of factors that are statistically significant drivers of price fluctuations both before and after the financial crisis also changed for some materials.
- The Model 1 factors driving price fluctuations for mixed paper did not change between the pre- and post-crisis months, nor did their quantitative influences change.
- Monthly price cycles prior to the financial crisis for newspaper, cardboard and PET included their dataset maximums attained during the 1994-95 pricing peaks for these materials. Aluminum can prices attained their maximum during 1988-89. Prices for mixed paper and HDPE peaked during their 1994-95 runs-up at levels nearly as high as their post-financial crisis peaks.
- Despite the pre-financial crisis period containing historic pricing peaks for many materials, average recycling market prices for newspapers, mixed paper, aluminum cans, tin cans, PET bottles and HDPE containers were higher after the financial crisis (thru June 2016) than they were before, some substantially. Average prices for tin cans more than doubled, mixed paper and HDPE containers were up more than 50%, and newspapers and PET containers were nearly 30% higher. By contrast, aluminum can prices were only 1% higher.
- As the exception, cardboard prices were 5% lower on average after the crisis.
- Prices for the paper commodities – newspaper, cardboard and mixed paper, along with PET bottles, trended down following their 2011 post-crisis recovery peaks until the first six months of 2016. PET had the strongest downtrend.
- Recycled material end-user prices for aluminum and tin cans and HDPE containers fluctuated following 2011 with no discernable trend up or down.
- Prices for three colors mixed glass have trended up since 2011.

The Summary section provides further discussion on this study's general conclusions. Tables 1 and 2 in that section also encapsulate many of the generalizations yielded from examining recycling price cycles and trends and their causes.

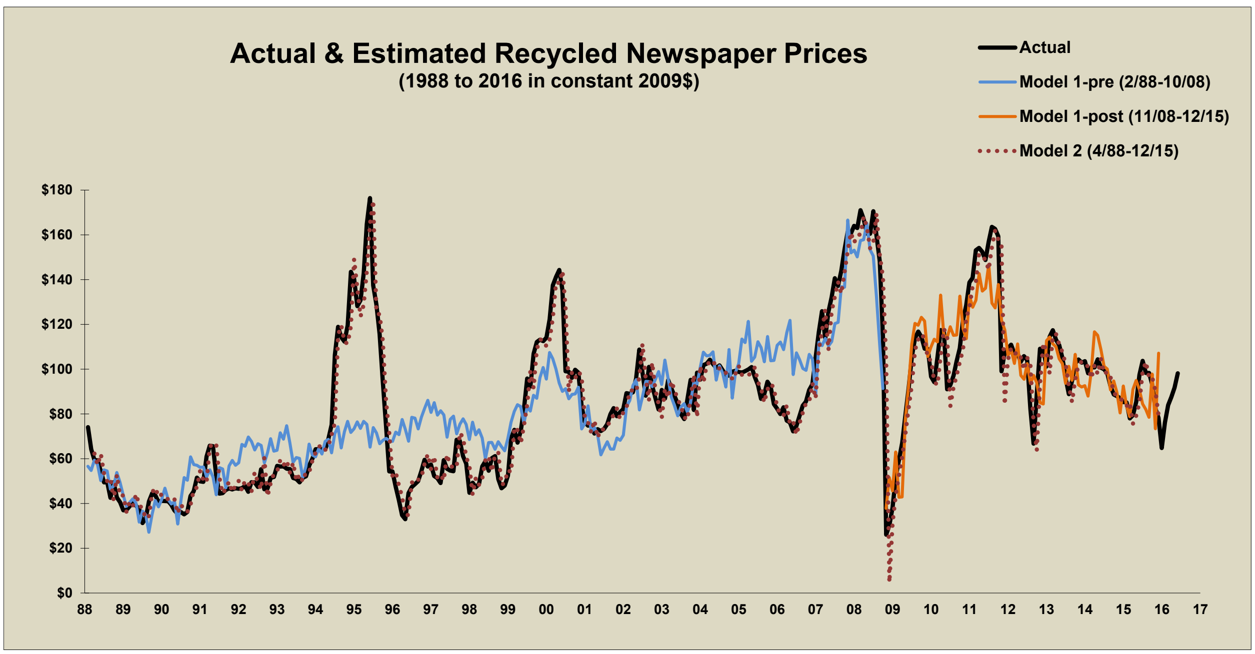
Recycled Newspaper Market Prices

Figure 2 charts monthly prices (FOB MRF; constant 2009$) for recycled newspaper received by one or more Puget Sound MRFs during February 1988 through June 2016. Price volatility is evident with cyclical peaks during 1994-95, 1999-2000, 2006-2008, and 2010-2011 and an extreme low in late 2008 during the financial crisis that started the Great Recession. There have been extended periods when mainly moderate prices prevailed, such as 2001-2006 and 2012-2016.

The figure shows Model 1-pre, Model 1-post and Model 2 outcomes from using these statistical techniques to fit explanatory equations to the historical price data for recycled newspapers. As shown by the graph, the Model 2 estimated equation fits the data best, in the sense that it most closely tracks actual prices. Model 1-post fits November 2008 through December 2015 data better than Model 1-pre fits February 1988 through October 2008. A statistical test showed that there was less than a 1% chance that a single Model 1 equation would fit the newspaper price series data better than the separate equations shown on Figure 2.

Table 4 lays out coefficient estimates for variables that were statistically significant in each model for explaining recycling price movements for newspapers. The first thing to note is that the Model 2 equation accurately explains the current price for recycled newspapers based only on prices in the previous two months and the twelve month rolling index of gross annual output for paper mills. There can be high correlations between economic factors that are all statistically significant in a model for explaining cycles and trends in a recycled material's market price. High correlations make it difficult to sort out the impact of each correlated variable. In such cases it may be important to use as few correlated explanatory variables as possible, while still obtaining the best fitting equation. The Model 2 equation for recycled newspaper prices is impressive in only needing to rely on one explanatory variable in addition to recycled newspaper prices for the previous two months.

Figure 2



At the same time Model 2 doesn't provide much insight into other variables that could influence movement in end-user pricing for recycled newspapers, or whether the list of influential variables might have changed recently. Model 1 equations provide both types of information. As shown by the coefficient estimates in Table 4 for the pre- and post-financial crisis Model 1 equations, in the post-crisis period:

- Gross annual output of paper mills, U.S. wage rates and China's real quarterly GDP growth rate are quantitatively more important,
- Crude oil prices are not statistically significant while the dollar's foreign exchange value is, and,

- Significant seasonal influences occur also in June, November and December, in addition to July and August.

Model 1 for both pre- and post-financial crisis periods estimates a statistically significant negative relationship between market price and quantity recycled in the U.S.. This is consistent with the downward sloping demand curves shown in Figure 1 and the assumption that other factors affecting recycled newspaper demand are held constant while quantity supplied varies slightly to trace out the demand curve.

One might summarize the pre- versus post-financial crisis changes by saying that end-user prices for recycled newspapers post-crisis are more dependent on foreign markets and on domestic demand for paper mill product outputs. This latter effect may be because domestic newspaper sales as well as newsprint production have declined substantially in recent years. As demand for recycled newspaper for making newsprint has declined, manufacturers of other types of paper products both overseas and domestically may increasingly use newspapers as part of the furnish for making their paper products.

Furthermore, if oil prices are indicative of overall energy costs, then the advantage of recycled newspaper over virgin wood chips and pulp in terms of energy usage is not as important as it was in the pre-crisis period when oil prices were trending sharply upwards. Crude oil peaked in June 2008 just before the crisis. Since the end of 2008 oil prices have fluctuated at much lower price levels, reaching an April 2011 post-crisis peak 18% below the June 2008 pre-crisis peak and trending down recently to a February 2016 bottom 75% below June 2008.

As a final note on recycled newspaper prices, both real (constant 2009 dollars) and nominal prices trended up during January through June of 2016. Also, real newspaper prices post crisis were 28% higher than pre-crisis and price variability (as measured by standard deviations in real prices) was 25% lower.

Table 4
Statistically Significant Coefficients for Newspaper Price Equation Explanatory Variables
(Standard errors shown in parentheses)

Explanatory Variables	Model 1-post Equation 11/08 - 12/15	Model 1-pre Equation 2/88 - 10/08	Model 2 Equation 4/88 - 12/15
GAO Index for US Paper Mills (2009=100)	2.74 (0.49)	0.61 (0.22)	0.67 (0.10)
US ONP Recycling Quantity (thousand tons)	-0.07 (0.02)	-0.05 (0.02)	not significant
Crude Oil Price (constant 2009 $/barrel)	not significant	1.34 (0.15)	not significant
US Industrial Electricity Price (constant 2009 cents/kWh)	-29.3 (8.2)	-32.0 (7.4)	not significant
US Average Wage Rate (constant 2009 $/hour)	14.65 (3.08)	9.88 (1.69)	not significant
US $ Foreign Exchange Value (foreign currency units/$)	-2.74 (0.39)	not significant	not significant
China Real Quarterly GDP Growth Rate (%)	36.3 (9.5)	11.1 (4.2)	not significant
<u>Lagged Newspaper Prices</u>			
Previous Month ONP Price			1.19 (0.05)
ONP Price Two Months Ago			-0.23 (0.05)
<u>Monthly Differentials ($/ton)</u>			
June	12.5 (5.7)	not significant	not significant
July	15.4 (6.6)	11.6 (5.0)	not significant
August	11.0 (5.8)	11.3 (4.9)	not significant
November	-19.9 (6.9)	not significant	not significant
December	-14.2 (6.9)	not significant	not significant

GAO = Gross Annual Output; ONP = Old Newspaper

Recycled Corrugated Cardboard Market Prices

Figure 3 charts monthly prices (FOB MRF; constant 2009$) for recycled cardboard received by one or more Puget Sound MRFs during January 1993 through June 2016. Price volatility is evident with cyclical peaks during 1994-95, 1997, 2000, 2002, 2007-2008, and 2010-2011 and an extreme low in late 2008 during the financial crisis that started the Great Recession. There have been extended periods when mainly moderate prices prevailed, such as 2004-2006 and 2012-2016.

The figure shows Model 1-pre, Model 1-post and Model 2 outcomes from using these statistical techniques to fit explanatory equations to the historical data for recycled cardboard end-user prices. As shown by the graph, the Model 2 estimated equation fits the data best, in the sense that it most closely tracks actual prices. A statistical test showed that there was less than a 9% chance that a single Model 1 equation would fit the cardboard price series data better than the separate equations shown on Figure 3. Model 1-post fits November 2008 through December 2015 data better than Model 1-pre fits January 1993 through October 2008. In part this may be because there is only one cyclical peak post crisis versus many peaks pre crisis. Model 1 equations for cardboard do not track cyclical peaks very closely, especially during the pre-crisis period.

Figure 3

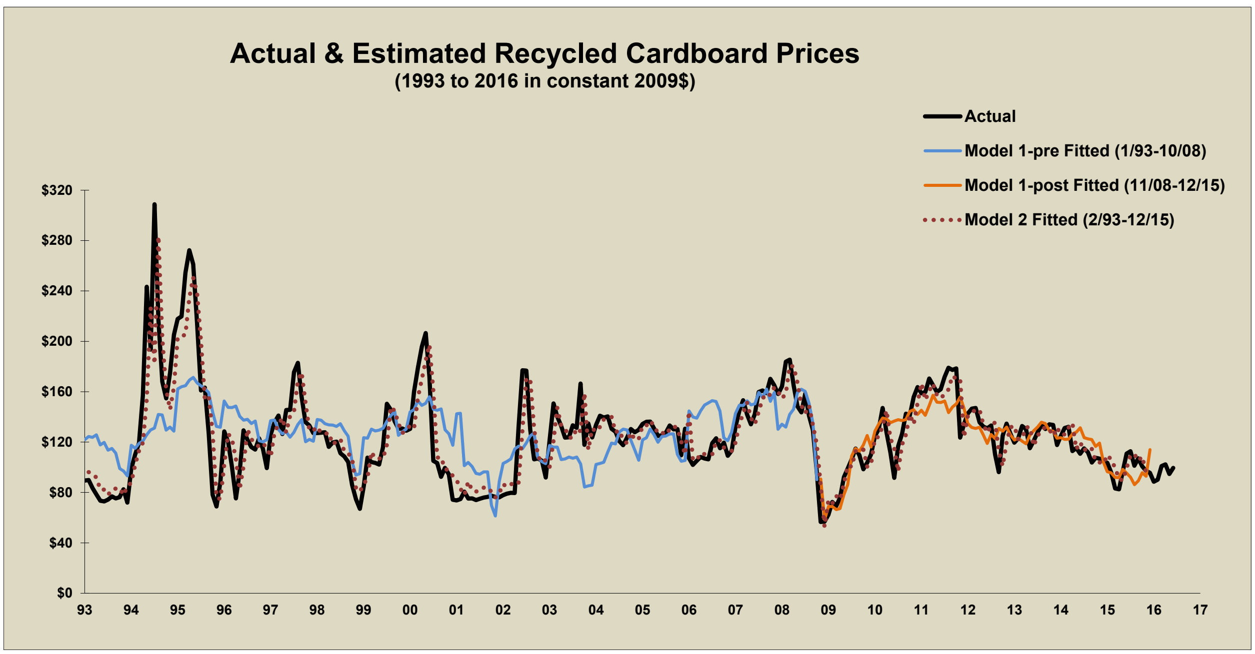


Table 5 lays out coefficient estimates for variables that were statistically significant in each model for explaining cardboard recycling price movements. The first thing to note is that the Model 2 equation accurately explains the current price for recycled cardboard based only on price in the previous month, the twelve month rolling index of gross annual output for paperboard mills, and crude oil prices.

At the same time Model 2 doesn't provide as much insight into other variables that influenced movement in end-user pricing for recycled cardboard, or whether the list of influential variables might have changed recently. Model 1 equations provide both types of information. As shown by the coefficient estimates in Table 5 for the pre- and post-financial crisis Model 1 equations, in the post-crisis period:

- Gross annual output of paperboard mills, crude oil prices, U.S. wage rates and an indicator for U.S. recessions are quantitatively less important,
- There is a statistically significant negative relationship between market price and U.S. cardboard recycling quantities,
- China's real GDP growth rate is a statistically significant influence, whereas it was not pre-crisis, and,
- There are no significant seasonal influences.

In sum, comparing pre- versus post-financial crisis months, end-user prices for recycled cardboard post-crisis are more dependent on foreign markets and somewhat less dependent on domestic demand for paperboard mill products. As discussed in the Summary and Conclusions section, export markets have been increasing in importance over time for cardboard collected and processed for recycling in the U.S. Furthermore, the advantage of recycled cardboard over virgin wood chips in terms of energy usage is not as important as it was in the pre-crisis period when oil prices were trending sharply upwards.

For recycled cardboard the economic slowdown in China, lower crude oil prices and the lower estimates of the quantitative impacts of economic factors post-crisis versus pre-crisis have together yielded the result that cardboard's recycling prices have fluctuated at a lower level on average post-crisis than they did prior to 2008. Real cardboard prices post crisis were 5.5% lower than pre-crisis, while price variability (as measured by standard deviations in real prices) was 34% lower. Furthermore, both real and nominal prices have trended irregularly downward since mid-2011.

Table 5
Statistically Significant Coefficients for Cardboard Price Equation Explanatory Variables
(Standard errors shown in parentheses)

Explanatory Variables	Model 1-post Equation 11/08 - 12/15	Model 1-pre Equation 1/93 - 10/08	Model 2 Equation 2/93 - 12/15
GAO Index for US Paperboard Mills (2009=100)	1.29 (0.41)	2.03 (0.52)	0.95 (0.10)
US OCC Recycling Quantity (thousand tons)	-0.01 (0.003)	not significant	not significant
Crude Oil Price (constant 2009 $/barrel)	0.60 (0.12)	0.82 (0.17)	0.35 (0.18)
US Industrial Electricity Price (constant 2009 cents/kWh)	not significant	not significant	not significant
US Average Wage Rate (constant 2009 $/hour)	-5.85 (2.71)	-7.54 (3.36)	not significant
Indicator for US Recessions ($/ton)	-25.1 (9.20)	-30.7 (10.7)	not significant
China Real Quarterly GDP Growth Rate (%)	28.8 (8.2)	not significant	not significant
Lagged Cardboard Prices			
Previous Month OCC Price			0.85 (0.06)
Monthly Differentials ($/ton)			
October	not significant	-18.1 (7.21)	not significant
November	not significant	-19.7 (7.76)	-5.56 (3.39)
December	not significant	-19.8 (8.51)	-7.38 (3.43)

GAO = Gross Annual Output; OCC = Old Corrugated Cardboard

Recycled Mixed Paper Market Prices

Figure 4 charts monthly prices (FOB MRF; constant 2009$) for recycled mixed paper received by one or more Puget Sound MRFs during February 1988 through June 2016. Price volatility is evident with cyclical peaks during 1994-95, 1999-2000, 2007-2008, and 2011 and extreme lows during 1993 and late 2008, the latter during the financial crisis that started the Great Recession. There have been extended periods of low prices in 1988-1993, as well as mainly moderate prices in 2003-2006.

The figure shows Model 1 and Model 2 outcomes from using these statistical techniques to fit explanatory equations to the historical price data for recycled mixed paper. As shown by the graph, the Model 2 estimated equation fits the data best, in the sense that it most closely tracks actual prices. A statistical test showed that there was not a significant chance that separate Model 1 equations would fit the mixed paper price series data better than the single Model 1 equation shown on Figure 3. The Model 1 equation for mixed paper does not track cyclical peaks very closely, especially the two that occurred prior to 2001. Model 1 does produce two substantial peaks after 2001, but they are not very well-timed relative to the actual peaks during 2007-2008 and 2011.

Figure 4

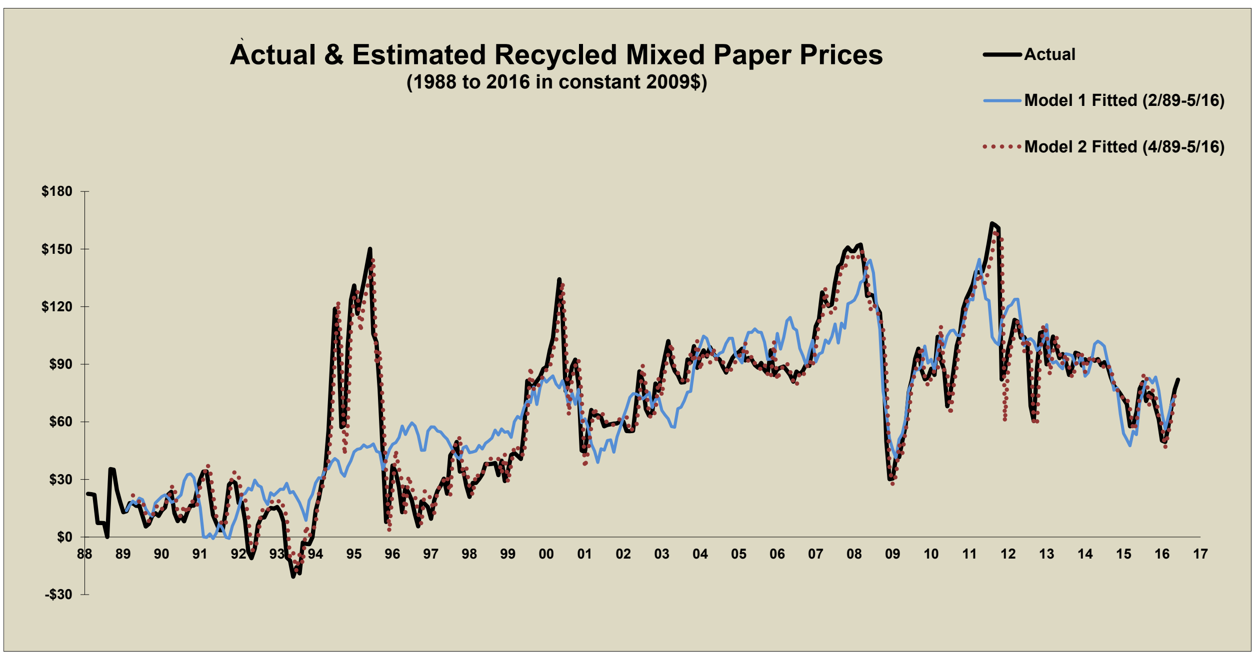


Table 6 shows coefficient estimates, along with their standard errors, for variables that were statistically significant in each model for explaining mixed paper recycling price movements. The Model 2 equation accurately explains the current price for recycled mixed paper based on prices in the previous two months, U.S. average wage rates, and the rate of growth in real GDP for India.

The fact that India is the country whose GDP growth is significant rather than China in both Models 1 and 2 is interesting. The negative influence of China's Green Fence in Model 1 may indicate some of the reason for India's importance vs. China as an overseas market for recycled mixed paper. Model 1 estimates statistically significant impacts for crude oil and U.S. industrial electricity prices, U.S. wages, an indicator for the imposition by China of its Green Fence beginning February 2013 and extending to the present day, GDP growth rate in India, and four consecutive positive monthly differentials for June through September. As with newspaper and cardboard the significant positive impact of oil prices may signal the importance of high energy prices as a driver of higher recycled mixed paper prices.

Table 6
Statistically Significant Coefficients for Mixed Paper Price Equation Explanatory Variables
(Standard errors shown in parentheses)

Explanatory Variables	Model 1 Equation 2/89 - 5/16	Model 2 Equation 4/89 - 5/16
Crude Oil Price (constant 2009 $/barrel)	0.93 (0.11)	not significant
US Industrial Electricity Price (constant 2009 cents/kWh)	-24.4 (3.34)	not significant
US Average Wage Rate (constant 2009 $/hour)	8.40 (1.26)	2.74 (0.72)
Indicator for China Green Fence ($/ton)	-16.3 (4.04)	not significant
India Real Quarterly GDP Growth Rate (%)	17.4 (5.67)	7.73 (4.39)
Lagged Mixed Paper Prices		
Previous Month Mixed Paper Price		1.21 (0.05)
Mixed Paper Price Two Months Ago		-0.28 (0.05)
Monthly Differentials ($/ton)		
June	10.8 (5.22)	not significant
July	17.4 (4.91)	not significant
August	14.9 (5.34)	not significant
September	9.05 (4.69)	not significant

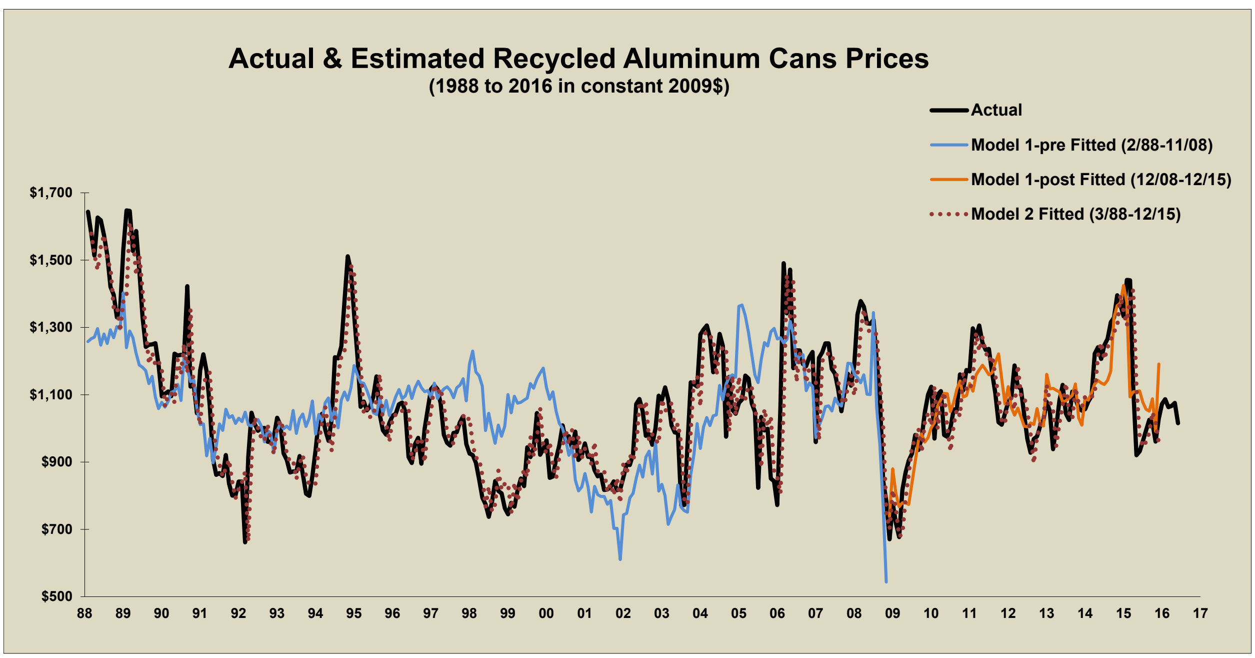
The negative impact of China's Green Fence is more than offset by the mixed paper price impact of India's real growth rate, which averaged 1.58% during the months following China's imposition of higher standards for imported recyclables. This may suggest that the U.S. mixed paper exports turned to Asian countries such as India for markets to replace Chinese markets after February 2013. GDP growth in China was not a significant explanatory variable for mixed paper prices in the Puget Sound region.

Mixed paper prices tended to drift downward following the 2011 peak until 2016. Both real and nominal mixed paper prices trended upward during the first six months of 2016. Both Models 1 and 2 tracked this upsurge. Real prices for mixed paper averaged $68 per ton over the 1988 through mid-2016 months covered by those models. Real prices for mixed paper were 55% higher after the financial crisis then they were during the pre-crisis months shown on Figure 1.

Recycled Aluminum Cans Market Prices

Figure 5 shows monthly prices (FOB MRF; constant 2009$) for recycled aluminum cans received by one or more Puget Sound MRFs during February 1988 through June 2016. Aluminum can prices show substantial price volatility and multiple cycles, some very short, with peaks in 1988, 1989, 1990, 1994-95, 2004, 2006, 2007-2008, 2011 and 2014. Extreme lows occurred during 1992 and 2008-09. There was an extended period of moderate cycles without any extreme highs or lows from 1996 through 2003.

Figure 5



The figure shows Model 1-pre, Model 1-post and Model 2 outcomes from using these statistical techniques to fit explanatory equations to the historical data for recycled aluminum can end-user prices. As shown by the graph, the Model 2 estimated equation fits the data best. Model 1-post fits better than Model 1-pre. A statistical test showed that there was less than a 1% chance that a single Model 1 equation would fit the aluminum can price series data better than two separate equations.

Table 7 lays out coefficient estimates for variables that were statistically significant in each model for explaining aluminum can recycling price movements. The first thing to note is that the Model 2 equation accurately explains the current price for recycled aluminum cans based only on price in the previous month and the twelve month rolling index of gross annual output for aluminum sheet factories.

However, Model 2 doesn't provide insight into other variables that might influence end-user pricing, nor into whether the list of influential variables might have changed recently. Model 1 equations provide both types of information. As shown by coefficient estimates in Table 7 for the pre- and post-financial crisis Model 1 equations, the way exports manifest their influence on recycled aluminum can prices changed in the post-crisis period. Pre-crisis the foreign exchange value of U.S. dollars and West Coast port labor slowdowns affected pricing; whereas post-crisis real GDP growth in China replaced the dollar's foreign exchange value. West Coast port labor slowdowns continued to be significant, although 15% lower in quantitative impact.

In addition, industrial electricity prices in the U.S. have a depressing effect on recycled aluminum can prices post-crisis, but were not statistically significant pre-crisis; and the positive impact of aluminum sheet gross output is cut by more than half versus output's pricing influence pre-crisis. One might conclude that recycled aluminum can prices in recent years have come to be more dependent on export demand than on domestic aluminum sheet demand. U.S. electricity prices have exacerbated this dependence with prices 14% higher on average post-crisis compared with their pre-crisis average.

Finally, both real and nominal prices have continued to fluctuate up and down in recent months, although they have trended up on average since reaching bottom during May-June 2015. Real recycled aluminum can prices post crisis were 1% higher than pre-crisis, while price variability (as measured by standard deviations in real prices) was 25% lower.

Table 7
Statistically Significant Coefficients for Aluminum Cans Price Equation Explanatory Variables
(Standard errors shown in parentheses)

Explanatory Variables	Model 1-post Equation 12/08 - 12/15	Model 1-pre Equation 2/88 - 11/08	Model 2 Equation 3/88 - 12/15
GAO Index for US Aluminum Sheet Factories (2009=100)	7.60 (0.79)	16.7 (2.07)	8.31 (0.39)
Crude Oil Price (constant 2009 $/barrel)	not significant	not significant	not significant
US Industrial Electricity Price (constant 2009 cents/kWh)	-53.2 (20.3)	not significant	not significant
US Average Wage Rate (constant 2009 $/hour)	not significant	not significant	not significant
US $ Foreign Exchange Value (foreign currency units/$)	not significant	-8.41 (1.71)	not significant
Indicator for West Coast Port Labor Slowdowns ($/ton)	272.7 (33.1)	319.5 (60.9)	not significant
Indicator for Export Spike Pre-2014-15 Slowdown ($/ton)	153.7 (28.8)		not significant
China Real Quarterly GDP Growth Rate (%)	217.2 (38.6)	not significant	not significant
<u>Lagged Aluminum Can Prices</u>			
Previous Month Aluminum Can Price			0.90 (0.06)
<u>Monthly Differentials ($/ton)</u>			
November	-102.9 (27.0)	not significant	not significant
December	-90.6 (34.3)	not significant	not significant

GAO=Gross Annual Output

Recycled Tin Cans Market Prices

Figure 6 shows monthly prices (FOB MRF; constant 2009$) for recycled tin cans received by one or more Puget Sound MRFs during February 1988 through June 2016. Tin can prices were remarkably stable from 1988 until late 2003, showing only a drop to lower levels late in 1998 through 2002, then a step back up toward the near $50 per ton level that prevailed for most months during 1988 through 1998. After 2003 recycled tin cans price volatility was similar to volatility in prices for other recycled materials, with peaks in 2004, 2008, 2011 and 2014. The late 1990s and early 2000s were a period when zero and below zero prices prevailed, levels not reached even during the financial crisis of 2008.

Figure 6

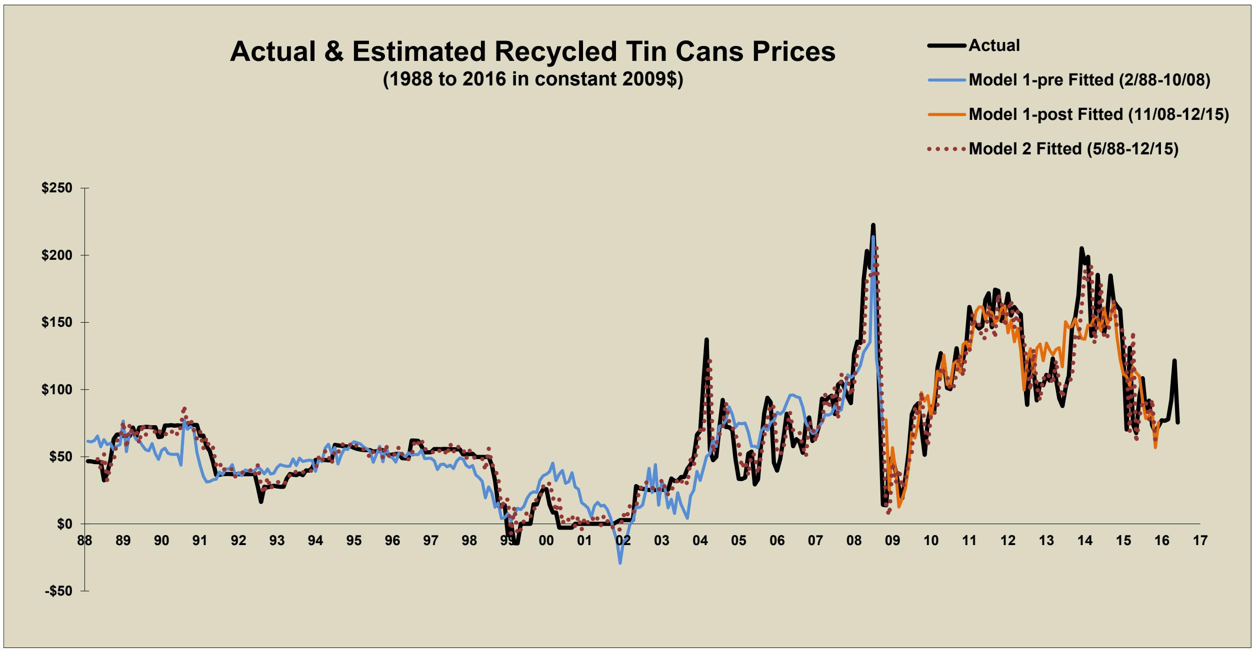


Figure 6 shows Model 1-pre, Model 1-post and Model 2 outcomes from using these statistical techniques to fit explanatory equations to the historical data for recycled tin can end-user prices. Model 2's estimated equation fits the data best. Model 1-post and Model 1-pre also fit the actual price data quite well, even tracking most of the cyclical ups and downs. A statistical test showed that there was less than a 1% chance that a single Model 1 equation would fit the tin can price series data better than two separate equations.

Table 8 lays out coefficient estimates for variables that were statistically significant in each model for explaining tin can recycling price movements. Model 2's equation accurately explains the current price for recycled tin cans based on prices in the previous three months, the gross output index for U.S. iron and steel mills, U.S. iron and steel industry capacity utilization, crude oil prices, U.S. wage rates, and the June monthly pricing differential. The Model 2 equation for tin can prices is unusual in showing significant influences for five variables in addition to prices in previous months.

As indicated by coefficient estimates in Table 8 for the pre- and post-financial crisis Model 1 equations, the way exports manifest their influence on recycled tin can prices is different in the post-crisis period. Pre-crisis, West Coast port labor slowdowns affected pricing. Post-crisis, real GDP growth in China and the export volume spike in October just before the late 2014, early 2015 labor slowdown provided significant influences on tin can end-user pricing.

In addition, gross annual output (GAO) of iron and steel mills and U.S. wage rates had significant impacts on pricing post-crisis, both more than four times greater than in Model 2. GAO did not have a significant impact prior to the financial crisis, and U.S. wage rate impacts were nearly 60% lower.

Iron and steel industry capacity utilization was important in all three equations. However, in Model 1-post it was through month-to-month changes in utilization versus utilization in the current month for Model 1-pre and Model 2.

Note that no export demand metrics were significant in Model 2. Crude oil prices were significant at about the same impact level for all three equations.

Finally, both real and nominal prices have fluctuated up and down at lower levels in recent months compared with their 2013-2014 peaks. Real recycled tin can prices post crisis were 139% higher than pre-crisis; price variability was 26% higher.

Table 8
Statistically Significant Coefficients for Tin Cans Price Equation Explanatory Variables
(Standard errors shown in parentheses)

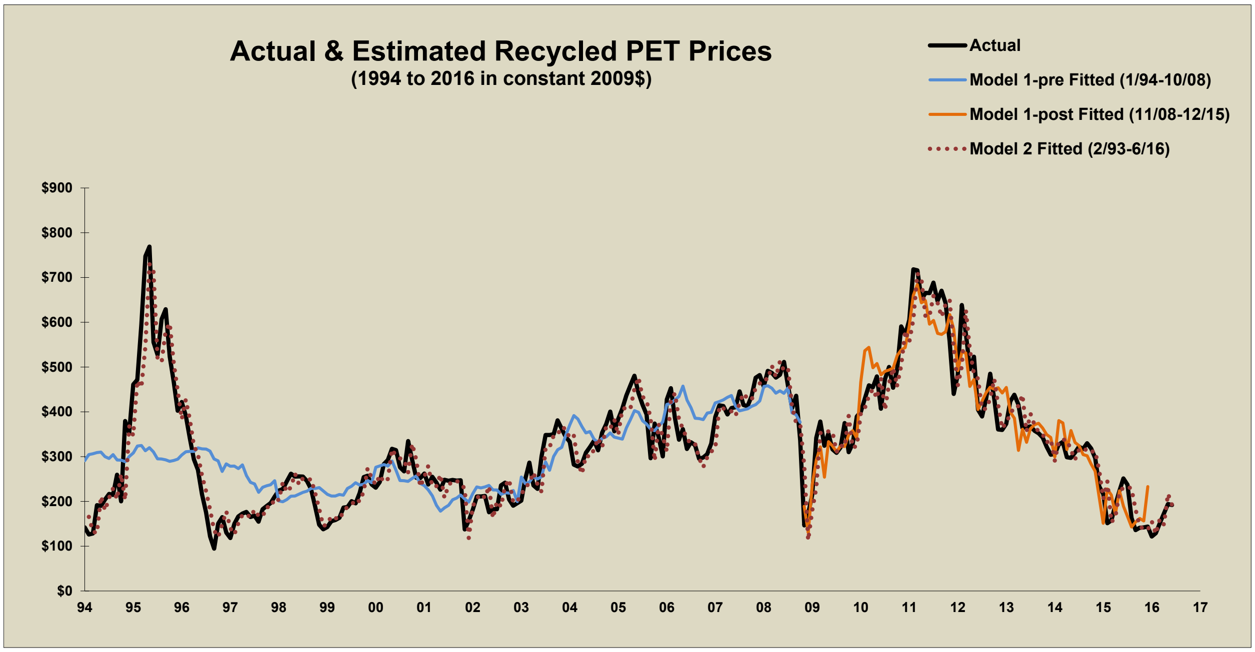
Explanatory Variables	Model 1-post Equation 11/08 - 12/15	Model 1-pre Equation 2/88 - 10/08	Model 2 Equation 5/88 - 12/15
GAO Index for US Iron & Steel Mills (2009=100)	2.15 (0.21)	not significant	0.47 (0.21)
Crude Oil Price (constant 2009 $/barrel)	0.92 (0.25)	0.94 (0.19)	0.83 (0.19)
US Industrial Electricity Price (constant 2009 cents/kWh)	not significant	not significant	not significant
US Average Wage Rate (constant 2009 $/hour)	-15.6 (1.19)	-6.74 (0.77)	-4.15 (1.24)
US Iron & Steel Industry Capacity Utilization (%)	not significant	1.48 (0.13)	0.54 (0.19)
US I & S Capacity Utilization % Change from Previous Month	228.6 (72.1)	not significant	not significant
Indicator for West Coast Port Labor Slowdowns ($/ton)	not significant	102.8 (16.4)	not significant
Indicator for Export Spike Pre-2014-15 Slowdown ($/ton)	23.1 (5.8)		not significant
China Real Quarterly GDP Growth Rate (%)	19.7 (6.9)	not significant	not significant
Lagged Tin Can Prices			
Previous Month Tin Can Price			0.93 (0.05)
Tin Can Price Two Months Ago			-0.25 (0.07)
Tin Can Price Three Months Ago			0.20 (0.05)
Monthly Differentials ($/ton)			
June	-15.7 (5.9)	not significant	-3.66 (2.03)

GAO = Gross Annual Output; I & S = Iron & Steel

Recycled PET Bottles Market Prices

Figure 7 shows monthly prices (FOB MRF; constant 2009$) for recycled PET bottles received by one or more Puget Sound MRFs during January 1994 through June 2016. PET prices had an historic peak during 1995. Prices fell to historic lows in 1996, and then began a relatively stable upward trend until the financial crisis. Since that crisis PET prices have had one cycle from the lows of late 2008 to peaks in 2011-2012 and back down to the bottom by late 2015. Prices have trended up in 2016.

Figure 7



The figure shows Model 1-pre, Model 1-post and Model 2 outcomes from using these statistical techniques to fit explanatory equations to the historical data for recycled PET bottle end-user prices. Model 2's estimated equation fits the data best as can be seen from how closely its estimates for prices follow actual prices, through even the big run-ups and declines in 1995-1996 and 2010-2012. Model 1-post also fits the actual price data quite well, including the 2011-2012 peaking. Model 1-pre did not track the 1994-1995 price cycle at all. A statistical test showed that there was less than a 1% chance that a single Model 1 equation would fit the PET price series data better than two separate equations.

Table 9 lists coefficient estimates for variables that were statistically significant in each model for explaining PET recycling price movements. Model 2's equation accurately explains the price for recycled PET bottles based on price in the previous month, crude oil prices, U.S. synthetic fiber industry capacity utilization, and February, March and May seasonal monthly pricing differentials.

Model 1-post accurately explains PET prices since the financial crisis and, in addition, provides estimates for impacts of additional economic factors not significant in Model 2's equation. These drivers include gross annual output for U.S. fiber mills, China's real GDP growth rate, and an indicator for the impact of China's Green Fence. Furthermore, synthetic fiber capacity utilization's impact is over 5 times greater in this Model 1 equation than in Model 2's estimated equation for explaining PET price cycles and trends.

Model 1-pre estimates for fiber mill gross output and synthetic fiber industry output capacity utilization indicate a weaker impact for those economic variables prior to the 2008 financial crisis than afterward. Real GDP growth in India impacted pre-crisis prices rather than China GDP growth. Higher crude oil prices were associated with higher recycled PET price levels after 2008, but were not a statistically significant factor in determining pre-crisis PET prices.

Finally, average recycled PET prices post 2008 crisis were 29% higher than pre-crisis. Price variability was 22% greater post-crisis, reflecting the relative price stability for recycled PET bottles pre-crisis during 1997 through 2008 when pricing climbed moderately without substantial fluctuations around the uptrend. Both real and nominal PET prices turned steadily upward during the first five months of 2016, moderating slightly in June.

Table 9
Statistically Significant Coefficients for PET Price Equation Explanatory Variables
(Standard errors shown in parentheses)

Explanatory Variables	Model 1-post Equation 11/08 - 12/15	Model 1-pre Equation 1/94 - 10/08	Model 2 Equation 2/94 - 6/16
GAO Index for US Fiber Mills (2009=100)	-8.33 (1.15)	-2.67 (0.64)	not significant
Crude Oil Price (constant 2009 $/barrel)	3.02 (0.45)	not significant	2.25 (0.54)
US Industrial Electricity Price (constant 2009 cents/kWh)	not significant	not significant	not significant
US Average Wage Rate (constant 2009 $/hour)	not significant	not significant	not significant
US Synthetic Fiber Industry Capacity Utilization (%)	11.3 (1.60)	.738 (1.84)	2.27 (0.51)
Indicator for West Coast Port Labor Slowdowns ($/ton)	not significant	45.8 (23.7)	not significant
China Real Quarterly GDP Growth Rate (%)	99.9 (29.6)	not significant	not significant
China Green Fence ($/ton)	-120.7 (30.2)		not significant
India Real Quarterly GDP Growth Rate (%)	not significant	64.6 (24.6)	not significant
<u>Lagged PET Prices</u>			
Previous Month PET Price			0.93 (0.06)
<u>Monthly Differentials ($/ton)</u>			
February	78.2 (28.4)	not significant	18.6 (7.8)
March	67.9 (21.6)	not significant	14.9 (7.8)
May	36.5 (13.1)	not significant	12.0 (6.7)

GAO = Gross Annual Output

Recycled HDPE Containers Market Prices

Figure 8 shows monthly prices (FOB MRF; constant 2009$) for recycled HDPE containers received by one or more Puget Sound MRFs during January 1993 through June 2016. HDPE container prices show substantial price volatility and multiple cycles, some very short, with peaks in 1995, 1997-1998, 2006, 2008, and 2014. Extreme lows occurred during 1999, 2003 and 2008. Prices have trended up during the first six months of 2016.

Figure 8

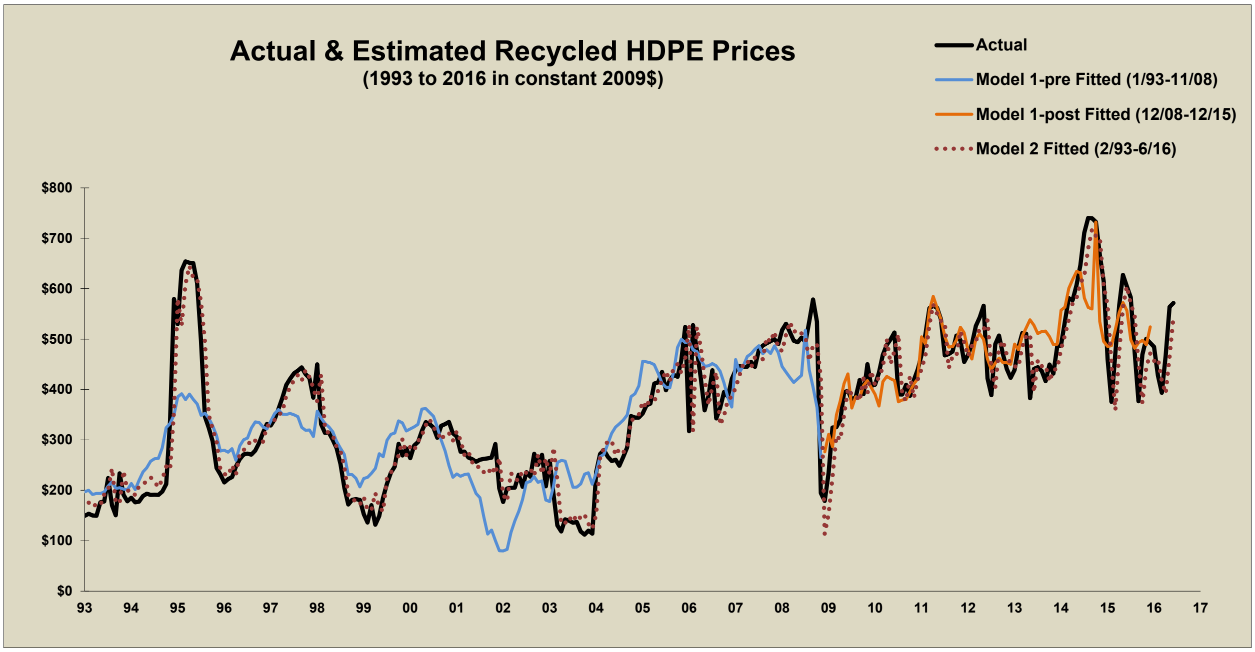


Figure 8 shows Model 1-pre, Model 1-post and Model 2 explanatory equations for recycled HDPE container end-user prices. Overall Model 2's estimated equation fits the data best as can be seen from how closely its estimates for prices follow actual prices, through even the big run-ups and declines in 1995-1996 and 2013-2014. Model 1-post also fits the actual price data quite well, including the 2013-2014 peaking. Model 1-pre did not track the 1995 or 1997 cyclical peaks well at all. A statistical test showed that there was less than a 9% chance that a single Model 1 equation would fit the HDPE price series better than two separate equations.

Table 10 lists coefficient estimates for variables that were statistically significant in each model for explaining HDPE recycling price movements. Model 2's equation accurately explains the price for recycled HDPE containers based on price in the previous month, crude oil price, U.S. wages, and U.S. plastics industry capacity utilization.

Model 1-post accurately explains HDPE prices since the financial crisis and, in addition, provides estimates for impacts of additional economic factors not significant in Model 2's equation. These drivers include gross annual output for U.S. plastic resins manufacturers, China's real GDP growth rate, and an indicator for the impact of the October export volumes spike prior to the 2014-2015 West Coast ports labor slowdown. Furthermore, U.S. plastic industry capacity utilization's impact is more than double in this Model 1 equation than in Model 2's estimated equation for explaining HDPE price cycles and trends.

Model 1-pre estimates for plastics industry output capacity utilization indicate a much weaker impact on pre-2008 crisis HDPE prices from an increase in capacity utilization than is the case post crisis. Real GDP growth in China and crude oil prices impacted post-crisis prices, but were not statistically significant factors in determining pre-crisis HDPE prices. On the other hand, U.S. wage rates and the overall indicator for West Coast port labor slowdowns were significant pricing drivers pre-crisis, but were not following 2008. Seasonal influences for March through June were only significant in Model 1-post's equation.

Lastly, recycled HDPE prices post 2008 crisis were 53% higher than pre-crisis on average; whereas price variability was 21% lower post-crisis. Both real and nominal HDPE prices trended upward during March through June of 2016.

Table 10
Statistically Significant Coefficients for HDPE Price Equation Explanatory Variables
(Standard errors shown in parentheses)

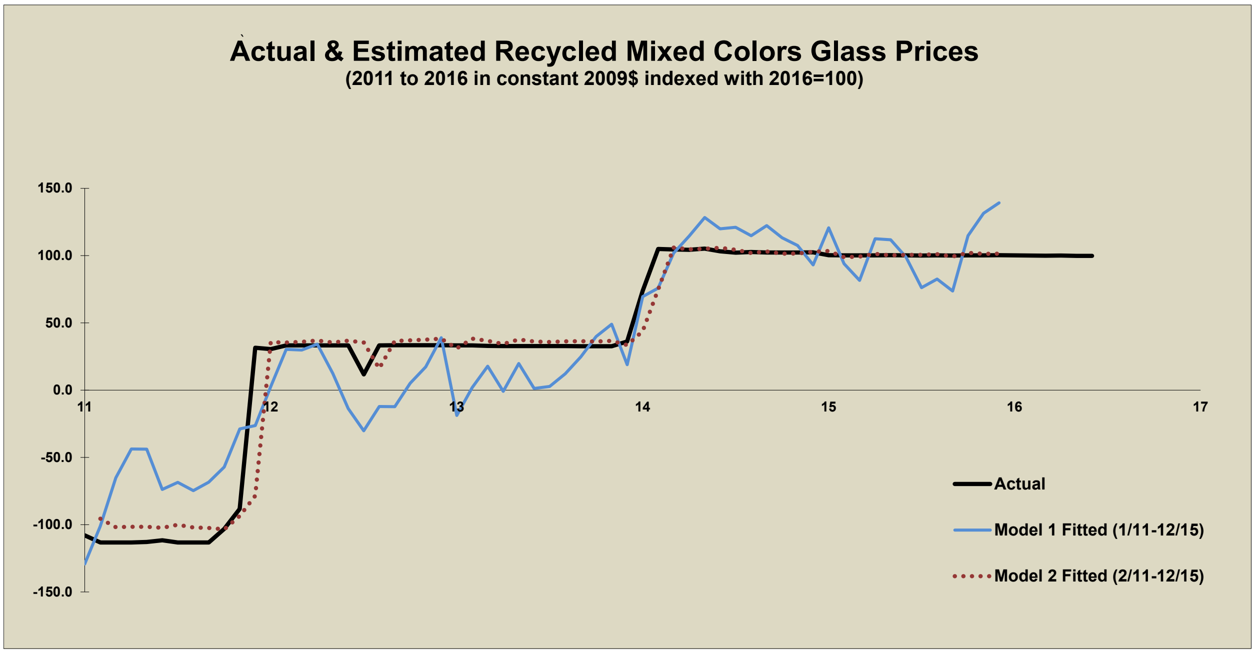
Explanatory Variables	Model 1-post Equation 12/08 - 12/15	Model 1-pre Equation 1/93 - 11/08	Model 2 Equation 2/93 - 6/16
GAO Index for Plastic Resins (2009=100)	-11.29 (2.40)	4.83 (0.63)	not significant
Crude Oil Price (constant 2009 $/barrel)	2.95 (0.80)	not significant	2.24 (0.63)
US Industrial Electricity Price (constant 2009 cents/kWh)	not significant	not significant	not significant
US Average Wage Rate (constant 2009 $/hour)	not significant	-34.8 (6.27)	-25.9 (5.47)
US Plastics Industry Capacity Utilization (%)	19.4 (3.21)	4.95 (1.83)	8.92 (1.27)
Indicator for West Coast Port Labor Slowdowns ($/ton)	not significant	95.1 (51.3)	not significant
Indicator for Export Spike Pre-2014-15 Slowdown ($/ton)	190.3 (24.3)	not significant	not significant
China Real Quarterly GDP Growth Rate (%)	54.6 (17.8)	not significant	not significant
Lagged HDPE Prices			
Previous Month HDPE Price			0.90 (0.06)
Monthly Differentials ($/ton)			
March	33.8 (17.4)	not significant	not significant
April	48.8 (19.4)	not significant	not significant
May	55.4 (30.0)	not significant	not significant
June	40.5 (23.3)	not significant	not significant

GAO = Gross Annual Output

Recycled Mixed Colors Glass Containers Market Prices

Figure 9 shows an index (January through June 2016 = 100) for three color mixed glass container prices received by a Portland region MRF during January 2011 through June 2016. AS indicated by the graph, these glass prices were quite stable over three different periods, stepping up once in late 2011 and again in late 2014-early 2015, and staying relatively constant otherwise.

Figure 9



The figure shows Model 1 and Model 2 explanatory equations for the recycled color mixed glass container price index. Model 2's estimated equation fits the index movements best, except for lagging a month behind at the two times when the price index stepped up. Model 1 fits the index data less well.

Table 11 lists coefficient estimates for variables that were statistically significant in each model for explaining mixed color glass recycling price movements. Model 2's equation accurately explains the price index for recycled glass containers based only on the index value in the previous month and the gross annual output index for U.S. glass container manufacturers.

Model 1 fits the actual price index values more loosely, but provides estimates for pricing impacts of additional economic variables – in this case crude oil prices, U.S. industrial electricity prices and U.S. average wage rates. In addition, gross annual output for glass manufacturers has an impact that is more than 12 times greater than its impact in Model 2's estimated explanatory equation.

As indicated on Figure 9, the recycled glass container price index trended up throughout the five and a half year period ending June 2016, except for one dip in July 2012.

Table 11

Statistically Significant Coefficients for Mixed Colors Glass Price Equation Explanatory Variables

(Standard errors shown in parentheses)

Explanatory Variables	Model 1 Equation 1/11 - 12/15	Model 2 Equation 2/11 - 12/15
GAO Index for US Glass Container Factories (2009=100)	0.10 (0.01)	0.008 (0.003)
Crude Oil Price (constant 2009 $/barrel)	0.01 (0.003)	not significant
US Industrial Electricity Price (constant 2009 cents/kWh)	-0.49 (0.19)	not significant
US Average Wage Rate (constant 2009 $/hour)	-0.50 (0.07)	not significant
Lagged Mixed Glass Prices		
Previous Month Mixed Glass Price		0.95 (0.13)

Appendix: Significant Economic Variables and Sources

Industry and Commodity Producer Price Indices are available from Bureau of Labor Statistics at http://www.bls.gov/ppi/ .

Industry Gross Annual Output (GAO) Indices (2009 = 100) are available from the Bureau of Economic Analysis, U.S. Department of Commerce at http://www.bea.gov/industry/gdpbyind_data.htm . These annual output indices for each industry were distributed across months based on monthly capital utilization for each industry.

Industry Capacity Utilization Percentages are available on a monthly basis from the Board of Governors of the Federal Reserve System in Table G.17 – Industry Capacity Utilization (percentage) at http://www.federalreserve.gov/feeds/g17.html .

U. S. Annual Recycling Quantities are mainly available through periodic U.S. EPA reports, e.g., at https://www.epa.gov/sites/production/files/2015-09/documents/2013_advncng_smm_rpt.pdf ; through the American Forest & Paper Association at http://www.paperrecycles.org/statistics ; and through personal communication with Container Recycling Institute staff at http://www.container-recycling.org . Annual quantities were distributed across months based on Puget Sound city monthly collection quantities for each recycled material.

Crude Oil Prices are available for monthly averages from the Energy Information Administration, U.S. Department of Energy for Cushing OK WTI Spot Price FOB Daily (U.S. $/barrel) at https://www.eia.gov/opendata/qb.cfm?sdid=PET.RWTC.D .

U.S. Industrial Electricity Prices are available for monthly averages from the Energy Information Administration at http://www.eia.gov/electricity/data/browser/#/topic/7?agg=2,0,1&geo=g&freq=M .

U.S. Average Wage Rates are available from the Bureau of Labor Statistics, Current Employment Statistics (CES) survey, Average hourly earnings of production and nonsupervisory employees, manufacturing, not seasonally adjusted (series CEU300000008) at: http://www.bls.gov/data/ .

U.S. Dollar Foreign Exchange Value is available from the Board of Governors of the Federal Reserve System in Table H.10, Nominal Broad Dollar Index-Monthly Index (rates in currency units per U.S. dollar) at http://www.federalreserve.gov/releases/h10/summary/indexb_m.htm .

U.S. Recession Months Indicator is available through the Public Information Office, National Bureau of Economic Research, Business Cycle Dating Committee, Cambridge, MA at http://www.nber.org/cycles.html .

U.S. Real Quarterly GDP is available through the Bureau of Economic Analysis (BEA) at http://www.bea.gov/national/nipaweb/DownSS2.asp . Rolling monthly totals interpolated from quarterly totals.

China Real GDP is available quarterly through the National Bureau of Statistics of China (NBS) at http://data.stats.gov.cn/English/easyquery.htm?cn=CO1 . Rolling monthly totals for quarterly GDP interpolated from quarterly totals.

India Real GDP is available through the Reserve Bank of India (RBI), Database on Indian Economy at http://dbie.rbi.org.in/DBIE/dbie.rbi?site=statistics . Rolling monthly totals for quarterly GDP interpolated from quarterly totals.

West Coast Port Labor Slowdowns Indicator and pre-2014-15 Slowdown Exports Spike constructed from internet searches yielding news and journal articles on West Coast port labor relations.