“The potential for exchange-traded futures on recycled materials to improve recycling efficiency”

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THE POTENTIAL FOR EXCHANGE-TRADED FUTURES ON RECYCLED MATERIALS TO IMPROVE RECYCLING EFFICIENCY

Abstract

Recycling has substantial environmental and economic benefits, but the recycling industry is relatively inefficient. Approximately half of all recyclable material is not actually recycled, and this inefficiency is economically and environmentally costly. This paper investigates the potential for exchange-traded futures on recycled materials to increase efficiency for the recycling industry by improving the market quality for firms that buy and sell recycled materials. The aim of this study is to statistically analyze a novel data set of prices for recycled materials to demonstrate the potential efficiency gains to introducing exchange-traded futures on recycled materials. The theoretical basis for this financial innovation is numerous previous studies showing that introducing exchange-traded derivatives improves the market quality of the underlying asset. The results of the analysis show that price volatility of recycled materials is generally high, with monthly standard deviation greater than 6%. Price volatility of recycled materials is excessive compared to price volatility of analogous new materials. Also, stock price volatility of waste management firms is positively related to price volatility in recycled materials. Price volatility of recycled materials explains 12% of the excess stock price volatility for waste management firms. This paper includes a practical discussion of proposed specifications and standards for these new financial contracts and plans for further research studies. Along with previous studies on the listing of exchange-traded derivatives, the conclusion of the statistical analysis is that there are large potential economic and environmental benefits to listing exchange-traded futures on recycled materials.

Keywords sustainability, efficiency, derivatives, volatility, market quality, financial innovation

JEL Classification Q20, G23, G29

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INTRODUCTION

Recycling holds the potential to prevent huge volumes of material from heading to landfills and incinerators. Yet, the realities of municipal and commercial recycling – volatility in prices, quality and quantity of available material – have made post-consumer materials (PCM) difficult to work with from the perspectives of large buyers and manufacturers. These users instead turn to new materials, while recyclables head to the dump. High PCM price volatility has negatively impacted the ability of PCM markets to function reliably, forcing many municipal waste services, PCM processing firms, and other market stakeholders to change the types and quantities of materials collected and processed. There is confusion among households and businesses as to what exactly can be recycled. Recyclable material that goes to the landfill and does not find new use as an input into productive activities is a market failure.

This paper proposes the theoretical listing of exchange-traded futures on recycled materials as a financial innovation to improve efficiency in the recycling industry. The theoretical basis for this argument is that, for a variety of underlying assets, the listing of exchange-traded derivatives contracts has improved the market quality for the underlying asset. The analysis in this paper utilizes a novel data set on the prices of commonly used recycled materials. One focus of the analysis compares the price volatility of recycled materials to analogous new materials. Another focus of the analysis is the relation between the price volatility of recycled new materials and the stock price volatility for firms in the waste management industry. This paper reviews the theoretical results and provides a discussion of two important practical issues associated with implementing this proposed financial innovation in practice: how to structure these contracts, and how to encourage potential buyers and sellers to trade these contracts. The theoretical basis and empirical results suggest that there would be substantial practical value to listing exchange-traded futures contracts on recycled materials: economic benefits for firms that buy and sell recycled material and environmental benefits for everyone.

1. THEORETICAL BASIS

It is abundantly clear that the municipal and commercial recycling industries do not always efficiently find new value for old materials as inputs into productive activities. For instance, the United States Environmental Protection Agency (USEPA) reports that 48.2% of the 292.4m tons of municipal solid waste generated in the US in 2018 was recyclable. However, only 48.9% of that eligible material was actually recycled. *Resource Recycling Magazine* documents a further decline in recycling rates during the COVID-19 pandemic (Staub, 2021).

Stakeholders, including buyers, sellers, and regulators, clearly recognize the importance of improving markets for the purchase and sale of PCM products. A 2021 *Wall Street Journal* article summarizes the trouble with the modern recycling industry (Ryan 2021). There is high PCM demand, driven by large multinational corporations, including Coca-Cola and Nestle, who pledge to improve sustainability by substantially increasing consumption of recycled materials. However, interested corporate buyers struggle to achieve sustainability pledges because of decentralized markets and uncertain prices. *Waste Dive*, an industry newsletter, documents a 50% spike in plastic resin prices in 2021 due to weather and supply chain issues (Thiruvengadam, 2021). The EPA's 2021 National Recycling Strategy establishes that the top objective is to "improve markets for recycled commodities through market development, analysis, manufacturing, and research." (USEPA 2021)

The recycling industry is inefficient because the supply chain that moves PCM from homes and businesses to processors to end users is far less consistent and efficient than the supply chain for new commodity materials. A major source of this inefficiency is that PCM are exclusively traded over-the-counter (OTC), through opaque personal networks of processors and brokers. The OTC marketplace lacks a centralized market mechanism for reporting price and volume information. Sellers face few repercussions for shipping PCM of variable or unacceptable quality. Subsequently, there is considerable variability in price, availability, and quality of PCM, making it much more difficult for large industrial users to develop reliable supply chains. These potential buyers of PCM instead turn to new materials, while recyclables head to landfills or incinerators.

This paper argues that the limited secondary market for PCMs is a fundamental barrier to connecting buyers and sellers and improving recycling efficiency. Developing exchange-traded derivatives on popular PCMs, such as glass and aluminum, would improve performance of recycling systems both economically and environmentally. Many efforts to reform the US recycling system have focused on public education or public subsidies to recycling operations in one form or another. Academic research into recycling typically focuses on the nuances of materials science or PCM processing operations. While there are surely engineering, materials science, and sociological dimensions to the recycled materials market failure, this paper focuses on barriers to increased usage of post-consumer materials (PCM) due to

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the markets and mechanisms for their exchange. This paper proposes a fundamentally different approach to reforming the US recycling system, focused on developing exchange-traded futures contracts. This potential solution would smooth out market volatility by providing greater price certainty to both buyers and sellers.

Considerable research has demonstrated that the introduction of derivatives markets can improve the quality of the spot market in the underlying asset because investors can use those derivatives to hedge risk exposure. In theory, derivatives also have potential to worsen the underlying spot market quality because speculators can use those derivatives to initiate highly leveraged positions that generate additional volatility. Yet the preponderance of evidence suggests that introducing derivatives has a significantly positive effect on the market quality of the underlying asset. Conrad (1989) focuses on the initiation of US exchange trading in single stock options during the 1970s and finds that introducing stock options reduces share price volatility. Bansal et al. (1989) show that introducing single stock options trading on the Chicago Board Options Exchange (CBOE) reduces the underlying stock's total volatility, entirely attributable to a reduction in idiosyncratic (non-systematic) volatility. Kumar et al. (1998) find that introducing listed equity options on US common stocks is associated with better market quality of the underlying stock along many dimensions: lower daily return variance, smaller average spreads, higher trading volume, and lower price impact. Other studies show an improvement in underlying asset market quality following the introduction of futures (Bessembinder & Seguin, 1992; McKenzie et al., 2001; Shastri et al., 2008) and exchange-traded funds (ETFs) (Hegde & McDermott, 2004).

The improvement in underlying market quality following the introduction of exchange-traded derivatives is not unique to the US equity market. Equity derivatives improve underlying market quality in several foreign-market and multiple-country studies (Bologna & Cavallo, 2002; Fong & Han, 2014; Antoniou & Holmes, 1995; Gulen & Mayhew, 2002; Alexakis, 2007; Lien & Zhang, 2008). Yao and Liu (2017) show that introducing exchange-traded commodity derivatives also improves market quality in associated underlying agricultural spot markets. The recent listing of exchange-traded Bitcoin futures is related to higher quality in the Bitcoin spot market (Kochling et al., 2019; Fassas & Papadamou, 2020; Kim et al., 2020).

The PCM futures contracts proposed in this paper would play a similar role to weather derivatives in allowing the ultimate buyers and sellers of recycled material to reduce operating risk. The introduction of exchange-traded weather derivatives is effective in allowing market participants with weather-related risk to reduce their exposure (Turvey, 2001; Brockett et al., 2005). Perez-Gonzales and Yun (2013) show that the ability to hedge weather risk exposure leads to higher hedging activity and increased stock market valuation for the most weather-exposed firms. Cornaggia (2013) finds that offering crop revenue insurance contracts leads to an increase in local agricultural productivity. Cole et al. (2017) find that providing the ability to hedge rainfall risk with an OTC derivatives contract leads to an increase in agricultural investment. Developing an exchange with standardized contracts for PCMs likewise can significantly improve the market quality for recycled materials and reduce the risk of businesses with exposure to commodity prices, while also spurring greater investment into this area of the US infrastructure. PCM derivatives will be of great interest to the largest waste management firms operating in the US, the top four of which together account for a combined 55% of the marketplace in PCM processing and related activities (Resource Recycling Systems 2020).

The purpose of this theoretical study is to analyze data on price volatility for recycled materials to provide support for the proposed financial innovation of listing exchange-traded futures contracts on recycled materials. There are two hypotheses associated with this theoretical study.

H1: The price volatility of recycled materials is higher than the price volatility of analogous new materials.

Currently, market participants can buy or sell exchange-traded futures on new materials, but not recycled materials. The absence of exchange-traded futures on recycled materials leads to high price volatility of recycled materials.

H2: The stock price volatility for waste management firms is higher when the volatility of recycled materials is higher.

The absence of exchange-traded futures on recycled materials means that waste management firms cannot hedge adverse shocks to future profits. Higher earnings volatility will lead to higher stock price volatility.

2. RESULTS

The analysis in this paper utilizes a novel dataset on PCM price volatility. The data source is a subscription website called recyclingmarkets.net. This website is a voluntary reporting mechanism for PCM transactions. Qualified end users such as manufacturers, materials recovery facilities, waste haulers, and other processing firms voluntarily provide both bid and offer prices for various PCM products. For each material, bid prices and offer prices are averaged for users in specific region and also nationally. The website reports prices for nearly 40 types of materials, representing the most common types of plastic, metal, glass, and paper fiber. However, in the case of many materials, there is very infrequent reporting of transactions so prices are very uninformative, and these price series are excluded from the study. Specifically, the analysis only includes the 13 materials in which more than half of the national monthly price changes are not zero. Table 1 contains more details on the materials themselves.

Table 1 shows summary statistics for monthly PCM prices from May 2005 to October 2020. Monthly prices are national averages of regional prices from recyclingmarkets.net. The PCM commodities in Panel A have prices quoted in US cents per pound. The PCM commodities in Panel B have prices quoted in US dollars per ton (2,000 pounds). For each PCM commodity, this table reports the maximum and minimum prices in the time series, the dates when the commodities traded at those extreme prices, the total percentage return from 2005 to 2020, and the percentage monthly standard deviation.

The first part of the empirical analysis compares the historical price changes for comparable new and recycled materials. For example, the analysis compares volatility in the historical prices for new glass with volatility in the historical prices of recycled glass. In the available data, there are three materials with significant price data for new and recycled materials: glass, aluminum, and paper. Data for the prices of recycled materials use national averages from recyclingmaterials.net. Data for the prices of new materials are from Bloomberg or the Federal Reserve of St. Louis website. The Bloomberg PPIJGLAS and FJPPALUM ticker prices proxy for the prices of new glass and new aluminum. The St. Louis Federal Reserve Producer Price Index by Commodity for Paper time series proxies for the price of new paper.

Table 1. Summary statistics on monthly PCM prices

Panel A: Prices Quoted in US Cents Per Pound				
PCM	**Max (Date)**	**Min (Date)**	**% Return**	**% SD**
Plastic PET Baled (#1)	36.5 (4/2011)	3.83 (1/2009)	–73.9%	12.0%
Natural HDPE (#2)	63.44 (10/2020)	11.69 (12/2008)	116.5%	12.6%
Colored HDPE (#3)	36.50 (10/2008)	3.58 (6/2020)	–31.6%	18.9%
Commingled (#1–#7)	10.90 (8/2011)	0.81 (10/2020)	–66.7%	14.1%
Polypropylene (#5)	15.25 (5/2016)	3.00 (5/2020)	–38.1%	10.4%
Aluminum Cans Baled	96.31 (5/2011)	39.13 (6/2020)	–29.3%	5.9%
Aluminum Cans Loose	82.81 (6/2007)	19.00 (6/2020)	–37.5%	7.2%
Panel B: Prices Quoted in US Dollars Per Ton (2,000 Pounds)				
PCM	Max (Date)	Min (Date)	% Return	% SD
Flint (Clear) Glass	45.00 (2/2018)	20.17 (1/2009)	39.2%	3.1%
Amber Glass	35.00 (2/2018)	8.00 (1/2009)	51.2%	5.4%
Green Glass	13.69 (5/2016)	4.42 (9/2005)	115.3%	7.6%
Sorted Residential Paper	158.57 (9/2008)	5.94 (4/2018)	–56.4%	32.6%
Corrugated Containers	180.00 (6/2017)	22.19 (12/2008)	–35.2%	15.7%
Sorted Office Paper	297.19 (8/2011)	82.81 (11/2020)	–23%	8.4%

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This paper examines the historical volatility of a portfolio of the four large publicly-traded US firms that dominate the waste management industry. The historical portfolio prices are constructed using monthly stock prices for the individual waste management firms from Bloomberg.

Table 1 provides summary statistics on 13 different types of PCM from May 2005 to October 2020. This includes all PCM contracts with listed national prices on the recyclingmarkets.net website in which more than 50% of monthly observations are non-zero price changes. The prices for these common PCM products are very volatile. Almost every product has a monthly standard deviation above 5% and many have monthly standard deviations of 10-15% or more.

The analysis utilizes an equal-weighted index of the 13 different types of PCM in the data. The top panel of Figure 1 shows the time series of index prices from May 2005 to October 2020, calibrated so that the index price is 100 in May 2005. The bottom panel of Figure 1 shows the time series of recycled index PCM volatility. Volatility is defined as the trailing-twelve-month standard deviation of monthly percentage price changes. Calculating the trailing-twelve-month average controls for seasonality in the volatility of any particular material. The price of the entire portfolio of PCM products is quite volatile, with a monthly standard deviation of more than 6%, spiking to 18% during the 2007–2009 financial crisis and again rising to more than 10% in 2018.

The top panel of Figure 1 shows the time series for an index of PCM prices from May 2005 to October 2020. The analysis employs an index constructed by forming an equal-weighted portfolio of 13 types of PCM. See Table 1 for summary statistics on each index component. Monthly prices are national averages of regional prices from recyclingmarkets.net. The index is calibrated to a value of 100 in May 2005. The bottom panel of Figure 1 shows the volatility of the PCM price index from May 2005 to October 2020. Volatility is the percent standard deviation of the last 12 monthly index returns.

Next, the analysis examines the relative volatility of new materials and analogous PCM products, with a focus specifically on paper, aluminum, and glass. These are the three materials with actively changing national monthly prices for recycled products on the recyclingmarkets.net website and actively changing monthly spot prices on either the Federal Reserve Bank of St. Louis website or Bloomberg. Figure 2 shows the time series of historical prices for new and recycled paper (top panel), aluminum (middle panel), and glass (bottom panel).

Figure 2 shows that from 2005 to 2020, the prices of recycled materials are substantially more volatile than the prices of analogous new materials. The standard deviation of monthly returns for recycled aluminum is only 3% larger than that of new aluminum. However, the standard deviation of monthly returns is more than 32 times larger

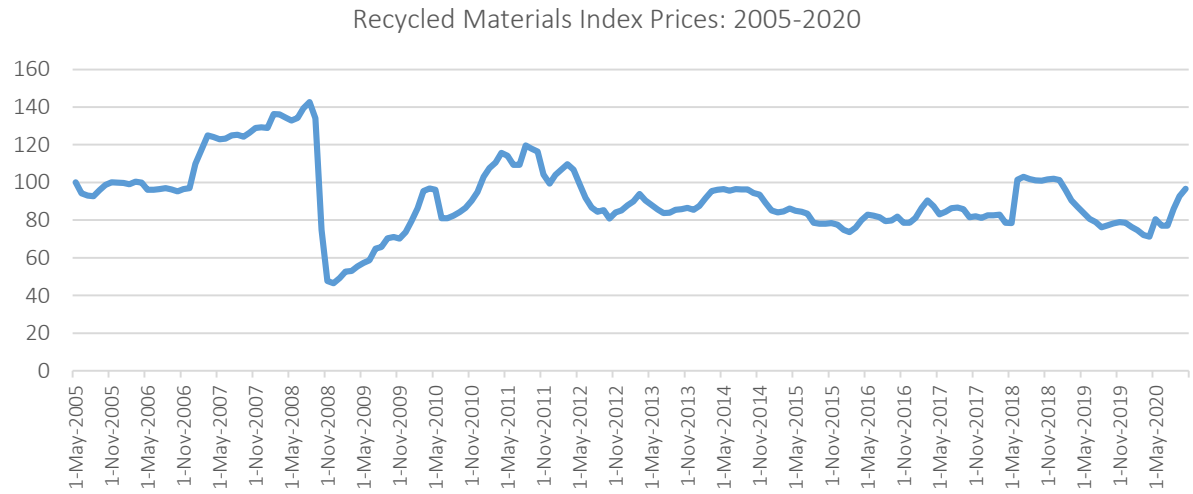

Figure 1. PCM price volatility

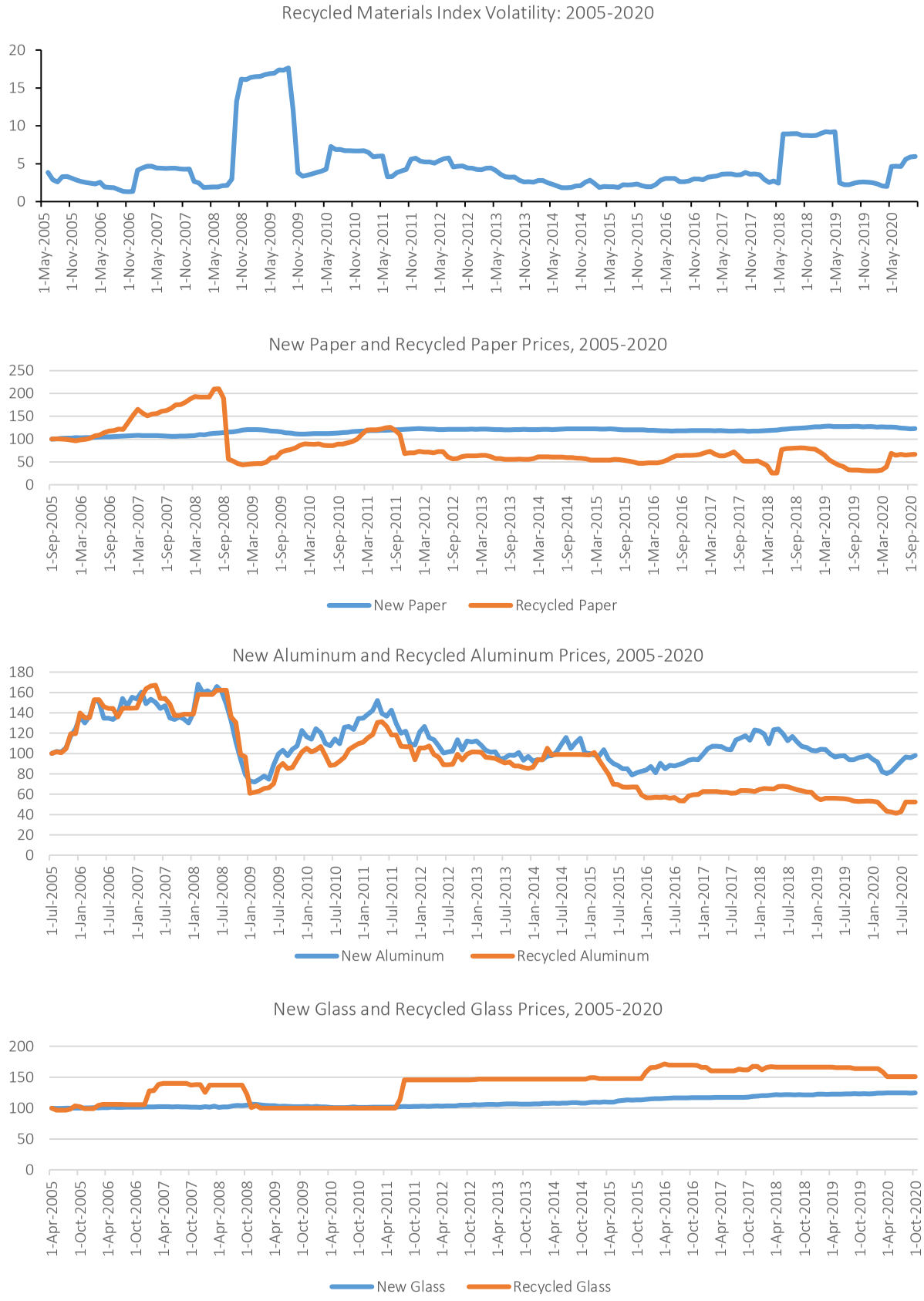

Figure 2. Price volatility for new and recycled products

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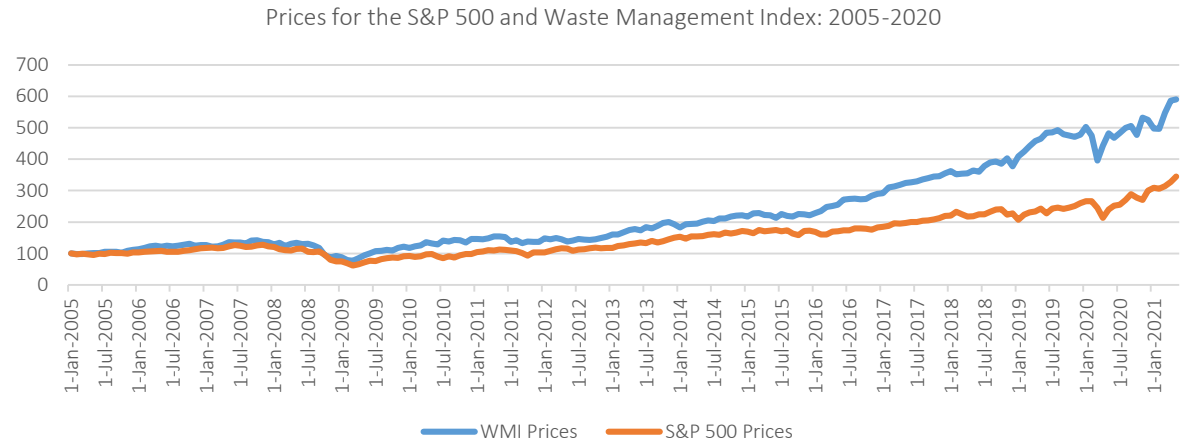

Figure 3. Price volatility for waste management stocks and the S&P500

for recycled paper than new paper and more than 7 times larger for recycled glass than new glass. Academic research consistently shows that introducing derivatives reduces price volatility in the underlying asset, as described in the Literature Review section of this paper. Therefore, listing exchange-traded futures in recycled PCM products would likely lead to lower volatility in recycled PCM prices, making recycled PCM relatively less unattractive than new material to end users.

The analysis examines whether stock price volatility for firms in the waste management industry is excessive due to volatility in PCM prices. This analysis utilizes a waste management index consisting of the four dominant stocks in the waste management industry (WMI4). The Van Eck Vectors Environmental Services ETF (Ticker: EVX) includes companies that, according to the prospectus, benefit from the global increase in demand for consumer waste disposal, removal, and storage of industrial byproducts, and the management of associated resources. Since the actual ETF trades very infrequently, this analysis utilizes an equal-weighted index of the four dominant stocks in the industry that each comprise around 10% of the index: Waste Connections Inc. (Ticker: WCN), Waste Management Inc. (Ticker: WM), Republic Services (Ticker: RSG), and Ecolab (Ticker: ECL). No other stock in the ETF has a weight of more than 4%.

Figure 3 shows the relative price volatility for new and recycled products from May 2005 to October 2020. The top figure compares new and recycled glass, the middle figure compares new and recycled paper, and the bottom figure compares new and recycled aluminum. Monthly new materials prices are from Bloomberg (glass, aluminum) or the St. Louis Federal Reserve (paper). Recycled materials prices are from recyclingmarkets.net. All prices are scaled to 100 as of May 2005.

Figure 3 shows the relative price volatility for a waste management index (WMI) and the S&P 500 index from May 2005 to October 2020. The analysis employs an index of waste management stocks constructed using an equal-weighted portfolio of the four dominant US firms operating in the waste management industry: Waste Connections Inc. (Ticker: WCN), Waste Management Inc. (Ticker: WM), Republic Services (Ticker: RSG), and Ecolab (Ticker: ECL). Both time series are scaled to 100 as of May 2005.

Figure 3 shows the returns of the Waste Management Index and the S&P 500 index from 2005 to 2020. The figure shows that waste management firms have earned approximately twice the percentage returns as the S&P 500 over the sample period with similar patterns in volatility. This paper formally tests the relation between market volatility and industry volatility by estimating a monthly time-series regression of absolute WMI index returns on absolute stock market index returns. Volatility is calculated using the absolute value of returns rather than the standard deviation of returns to ensure non-overlapping observations.

$$\left|r_{WMI,t}\right| = \beta_0 + \beta_1 \cdot \left|r_{SP500,t}\right| + \varepsilon. \quad (1)$$

Table 2 shows the statistical relationship between the volatility of waste management firm stock

Table 2. Volatility of waste management firm stock prices and PCM prices

Dependent variable	|r(WMI4)|	|r(WMI4)|	|r(WMI3)|	|r(WMI3)|
Intercept	1.12***	0.99***	1.69***	1.53***
|r(S&P 500)|	0.67***	0.63***	0.60***	0.55***
|r(PCM Index)|		0.08**		0.09**
Adj. R^2	0.415	0.428	0.275	0.292

Note: Statistical significance at the 10%, 5%, and 1% levels are indicated using ***, **, and *, respectively.

prices and the volatility of PCM prices. The analysis utilizes two different versions of a waste management index. The WMI4 is an equal-weighted average of the four largest US waste management industry stocks. The WMI3 is an equal-weighted average of the three largest US waste management stocks. The dependent variable of interest is the absolute value of the monthly return of the WMI4 or WMI3. The independent variables include the absolute value of the monthly return of the S&P 500 index and the absolute value of the monthly return of the PCM price index.

Table 2 shows the statistical relation between total market volatility and waste management industry volatility described by Equation (1). The coefficient estimate on β_1 is 0.67 with a t-statistic of 11.5. An additional 1% absolute S&P 500 index monthly return is associated with an additional 0.67% absolute waste management industry monthly return. The analysis also tests whether volatility in PCM prices is associated with higher volatility in waste management industry stock prices:

$$\left|r_{WMI,t}\right| = \beta_0 + \beta_1 \cdot \left|r_{SP500,t}\right| + \beta_2 \cdot \left|r_{PCM,t}\right| + \varepsilon. \quad (2)$$

In the analysis of waste management industry volatility described by Equation (2), the coefficient estimate on β_2 is 0.08 with a t-statistic of 2.29 (p = 0.023). An additional 1% absolute recycled index monthly return is associated with an additional 0.08% absolute waste management industry monthly return, even after controlling for the effect of stock market volatility. Adding the time series of recycled PCM prices as an explanatory variable reduces the magnitude of the intercept coefficient (β_0) estimate by 12%, suggesting that PCM price volatility contributes 12% of the volatility of the waste management industry after controlling for market volatility.

This paper tests for robustness by estimating the pair of linear regressions defined by Equation (1) and Equation (2) for an alternative method of calculating the waste management index. ECL is removed from the Waste Management Index and an equal-weighted index of the three remaining stocks (WMI3) is constructed. Ecolab stock is removed because the firm focuses more on environmental cleanup than conventional waste management. The coefficient estimate on β_2 is 0.09, and adding PCM volatility as an explanatory variable reduces the magnitude of the intercept coefficient estimate by 10%.

3. DISCUSSION

The empirical analysis in this paper provides support for the two hypotheses suggested by previous research on the effect of introducing exchange-traded derivatives on the market quality of the underlying asset. Hypothesis 1 is that the price volatility of recycled materials is higher than the price volatility of analogous new materials. Previous research suggests that introducing exchange-traded derivatives reduces volatility across a variety of asset classes, including US equities (Conrad, 1989), ETFs (Hegde & McDermott, 2004), commodity derivatives (Yao & Liu, 2017), and cryptocurrencies (Kim et al., 2020). The absence of exchange-traded futures on recycled materials leads to high price volatility of recycled materials relevant to analogous new materials. Although the standard deviation of monthly returns for recycled aluminum is only 3% larger than that of new aluminum, the standard deviation of monthly returns is more than 32 times larger for recycled paper than new paper and more than 7 times larger for recycled glass than new glass. The introduction of exchange-traded futures on recycled materials would allow buyers and sellers to lock in future prices and make using recycled materials relatively more attractive to using new materials.

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Hypothesis 2 is that the stock price volatility for waste management firms should be higher when the volatility of recycled materials is higher. The absence of exchange-traded futures on recycled materials means that waste management firms cannot hedge adverse shocks to future profits. Higher earnings volatility will lead to higher stock price volatility. The empirical results support this hypothesis. PCM price volatility contributes 12% of the volatility of the stock price volatility for firms in the waste management industry after controlling for market volatility. This result implies that waste management industry firms would benefit from the introduction of exchange-traded futures on PCM prices. Access to these derivatives markets would allow waste management firms to lock in future PCM prices and therefore reduce volatility in their earnings and stock returns. Lower earnings and stock price volatility would allow waste management firms to sell bonds or stock in external financial markets at a lower cost of capital. Exchange-traded PCM derivatives could have the same type of impact on real outcomes for waste management firms as weather derivatives have for stocks with significant weather risk: more intense hedging activity and higher stock market valuations (Perez-Gonzales & Yun, 2013), increased productivity (Cornaggia, 2013), and higher investment (Cole et al., 2017).

Since futures contracts on popular PCM products are not yet listed on an exchange, the interpretation of the results from the analysis are theoretical. Further studies are planned with an objective of persuading a major derivatives exchange to list and trade futures contracts on recycled materials.

4. FURTHER STUDIES

The biggest challenge with many market innovations is persuading firms and individuals to participate. Further studies to extend this theoretical paper will focus on developing a practical plan to implement the listing and trading of exchange-traded futures on recycled materials. PCM are currently traded entirely OTC via opaque personal networks of processors and brokers, without a centralized market mechanism for reporting price and volume information or clearing transactions. Transitioning from an OTC market to an exchange-traded environment is the most important avenue to a functional, active market for PCM derivatives. This particular barrier could be quite significant as the solid waste management industry has traditionally been conservative and slow to change unless required by regulation.

Certain attributes of the waste management industry and its component firms should result in considerable interest in the financial innovation described in this paper. Until the 1970s, waste management was a highly localized problem. Many towns had their own dumps and many neighborhoods within growing cities had their own incinerators. Waste haulers, until the 1980s, were typically small operations with one or two trucks and a handful of employees. As the ecological crisis of the 20th century became clear, though, and new types of regulations were imposed on the industry beginning in the US in the 1960s, certain advantages to larger scales could be realized. Firms emerged to combined vertical integration with ever-widening geographic scope. These nascent national firms moved to purchase not only rivals' collection and hauling businesses, but also disposal facilities – landfills, incinerators, and PCM processing plants. Mergers and acquisitions exploded among hauling firms in the 1990s and continue through today. As an illustration, a recent study observes that about 55% of materials recovery facilities in North America are operated by one of four large firms: Waste Management, Republic Services, Waste Connections, or GFL Environmental. Of those facilities, Waste Management owned 39%, Republic Services owned 28.5%, Waste Connections owned 20%, and GFL Environmental owned 12.5%. Within the past two years, each of these four firms has acquired at least one smaller firm in the industry, further entrenching their market power.

Further studies to develop this theoretical paper will focus on interviewing various stakeholders about their willingness to participate in trading exchange-listed derivatives contracts on various PCM products. These stakeholders include executives at major manufacturing and consumer corporations that would like to purchase recycled materials, executives at waste management firms that would like to sell recycled materials, executives on major derivatives exchanges, regulators, and other government officials. These interviews will also solicit feedback from stakeholders re-

garding standards and specifications for the exchange-traded futures contracts on various PCM products. The ideal futures contract for PCM could combine the Institute for Scrap Recycling Industry (ISRI) standards for quality and bale composition with the CME Group's specifications for trading commodities. ISRI guidelines specify composition and quality standards for many PCM products, but frequently leave terms of trade open for buyers and sellers to negotiate. To attract market participants, futures contracts require standards in quantity, quality, timing, and terms of trade. A PCM futures contract that combines ISRI's quality and composition standards with CME's contract standards would attract end users and other market participants to trade these contracts on a centralized exchange. Taken together, the combined standards would make considerable progress in improving the quality of PCM that is traded. Historically, quality of PCM loads has been variable and even subject to considerable deceit and manipulation by unscrupulous market participants (Howell, 2022). Strong quality standards built into the contracts would protect honest market participants and eventually force unscrupulous PCM brokers and traders out of the marketplace.

These statistics on waste management industrial organization provide context for the potential for PCM-linked exchange-traded derivatives. The waste management industry in North America is organized as an oligopoly. However, because most waste management services are regulated as utilities by state governments, there is likely a regulatory limit to profit margins that can be achieved by each firm for waste collection and disposal alone regardless of further consolidation. Thus, improving the profitability of recycling operations should be a strategic goal of at least the four major firms if not the majority of all service providers. At the moment, recycling – the processing and resale of PCM – is actually a fairly small portion of firm revenue compared to collection and disposal. For instance, as of January 2020, recycling activities accounted for just 6.8% of Waste Management's total revenue, 2.6% of Republic Services, and 1.3% of Waste Connections. Thus, improving the profitability of recycling operations should be an important avenue for major waste management firms to increase total profits. The Chief Sustainability Officer of Waste Management, Inc. noted in a recent interview that improving the performance of the recycling and organic waste management business lines is a "growth lever" for the firm. Listing exchange-traded PCM futures would reduce costs and price uncertainties of OTC PCM trading and potentially serve as that pathway to greater profitability. This in turn would entice increasing numbers of firms to participate in the new market, creating a critical mass of market participants that could revolutionize the entire industry.

CONCLUSION

The purpose of the study in this theoretical paper is to propose and analyze the listing of exchange-traded futures contracts as a mechanism to improve the efficiency of the recycling industry. The theoretical basis for this financial innovation relies on an extensive literature review associating the listing of exchange-traded derivatives with an improvement in market quality for the underlying asset. The empirical analysis of historical prices for recycled materials in this theoretical paper suggests that listing exchange-traded futures has potential to improve recycling efficiency. In particular, waste management firms that reduce risk by trading exchange-traded futures on recycled materials will be able to lower their stock price volatility and earnings volatility, allowing these waste management firms to borrow at lower rates, invest more aggressively, and increase stock market valuations.

The discussion in this theoretical paper highlights the idea that greater price certainty and transparency would encourage waste management firms to collect and sell more recycled material and encourage corporations to purchase more recycled material and honor their sustainability pledges. Further studies are organized around interviewing important stakeholders to determine their interest in listing and trading these new financial securities. In conclusion, the listing of exchange-traded futures on recycled material has tremendous potential benefits for the economy and the environment.

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AUTHOR CONTRIBUTIONS

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