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Can Markets Improve Recycling Performance? A Cross-Country Regression Analysis and Case Studies

Elena C. Prenovitz, Peter K. Hazlett * and Chandler S. Reilly

Department of Economics, George Mason University, Fairfax, VA 22030, USA
* Correspondence: phazlett@gmu.edu

Abstract: Can recycling reduce negative externalities created by landfills? Environmentalists argue yes; however, the efficiency of recycling will be institutionally contingent. Entrepreneurs will face less barriers to profit from recycling in countries with more economic freedom. Additionally, recycling conducted by private firms will be more cost-effective and have higher rates of innovation in recycling technology relative to a nationalized industry. The purpose of this study is to test these claims. First, a two-way fixed effects regression model is estimated using panel data from 34 countries over the years 2000 to 2019. Our regression results show that increases in economic freedom have a positive effect on recycling rates, independent of related policy effects. Second, using two brief case studies of the Republic of Korea and Taiwan, we show how the inefficiencies of bureaucratic management suggest that private industry can be a less costly solution to encouraging recycling. The empirical results and case studies strongly suggest that increases in economic freedom can be an important mechanism for increasing recycling rates, and private industry involvement in existing recycling programs can limit unnecessary costs.

Keywords: recycling; free market environmentalism; economic freedom; negative externalities; OECD countries; environmental policy

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1. Introduction

For decades now, recycling has been among the popular "green habits" to adopt as part of daily life. Many cities require that residents separate their trash so plastic bottles, glass bottles, and paper products can all be sent off to be broken down and repurposed as raw material to be used in production. Recycling centers collect waste for a nominal fee. Companies loudly advertise their products are made from "100% recyclable materials". Common to many of these trends are policies intended to directly encourage recycling, whether it is through subsidies or the threat of fines when individuals do not comply. Missing from the popular and academic conversation surrounding recycling is how free markets may help or inhibit more recycling and increased recycling efficiency.

We argue individuals will find it in their self-interest to recycle, conditional on the institutions permitting such behavior. Recycling tends to be costly relative to the value it creates such that any additional costs (e.g., transaction costs) can inhibit the development of markets in recycling. However, more economic freedom can lower transaction and other costs, ultimately leading to a higher expected value in recycling. Economic freedom, as used here, refers to institutions such as strong property rights, limited government regulation, and freedom to trade. Higher levels of economic freedom, then, can promote higher levels of recycling relative to a situation where economic freedom is more restricted.

Many researchers have studied the relationship between institutions, such as democratic governance and economic freedom, and environmental issues. Clulow and Reiner [1], for example, examine how democracy affects energy transition, finding that democracy has a significant effect on low-carbon energy sources. Similarly, earlier work from Graddy [2] shows that increases in the level of democracy in a country can have significant positive

effects on pollution reduction. Other research, more directly related to this paper, has assessed the relationship between economic freedom and environmental issues. Mahmood et al. [3] find evidence suggesting economic freedom can create an environment that encourages R&D activities that enhance energy-saving technologies and have a positive impact on the environment. Rapsikevicius et al. [4] present evidence from European countries showing mixed results of the effect economic freedom has on environmental performance and suggest a way to think about the optimal level of economic performance. Other tangentially related work has focused on the effect economic freedom can have on tourism [5].

Much of the research on the economics of recycling has focused on the efficiency of recycling and consumer behavior in recycling. For instance, Rapsikevicius et al. [6] propose a way of using blockchain technology in recycling programs to enhance coordination and efficiency in plastics recycling. Several other papers examine how entrepreneurship impacts innovation in recycling [7]; consumer perceptions of recycling [8]; consumer intentions to recycle at the end of a product's life using survey results and case studies [9,10]; and consumer recycling behavior in different settings [11,12]. These works, particularly those related to entrepreneurship, are conceptually linked to our focus on economic freedom. Countries with higher levels of economic freedom create the institutional conditions necessary to incentivize wealth-enhancing entrepreneurship [13]. However, existing research has not linked economic freedom to recycling specifically. Our intention is to bridge the gap between these two subjects by examining how institutions, specifically economic freedom, can affect recycling across countries using both panel data on 34 countries from 2000 to 2019 and two case studies.

The regression analysis using our panel data assesses the relationship between economic freedom and recycling rates while accounting for a variety of relevant controls and any year or country-specific heterogeneity to isolate our relationship of interest. Our regression estimates suggest there is a strong positive relationship between economic freedom and recycling rates, independent of policy effects. While those results do not illuminate the exact mechanism for this relationship, we explore how the strength of private industry and state intervention can affect recycling efficiency using two case studies. Not only do the case studies aid in understanding the mechanism by which economic freedom may positively affect recycling rates, they also complement the regression results in uncovering potential causal effects.

Our case studies examine recycling programs and industries in the Republic of Korea and Taiwan. These cases are useful for our purposes because they represent two examples where economic freedom moves in opposite directions, at least with respect to the management of recycling. In the Republic of Korea, the government implemented subsidies for recycling while leaving decision-making up to private industry for how to manage recycling. In Taiwan, the government nationalized the recycling industry. Both countries experienced increases in their recycling rates under drastically different policies. However, the institutional differences give reasons to believe that cost-efficiency across the two countries varies. the Republic of Korea's policies left recycling in the hands of private industry, allowing the incentives for cost minimization to guide decision making. In contrast, the nationalized recycling industry in Taiwan weakened the incentives for cost efficiency by leaving decision making up to government bureaucrats.

The empirical results and case studies presented in this paper contribute to the literature on free market environmentalism. Our evidence suggests that, despite the fact that our of measure economic freedom does not directly target recycling, it creates an environment conducive to more recycling by allowing individuals to exploit gains from trade. This also suggests that enhancing economic freedom along margins more directly related to recycling could have similar effects. The estimated relationship between economic freedom and recycling rates is also stronger than that between environmental policy stringency and recycling rates, suggesting further that economic freedom may play a more important role. If policymakers want to encourage more recycling, they can potentially make more

progress toward this goal without resorting to costly subsidies, recycling requirements, or a nationalized industry.

The rest of the paper proceeds as follows. Section 2 lays out the economics of recycling and provides some theoretical justifications for why economic freedom can positively affect recycling. Section 3 presents our methodology including the data description and empirical strategy. Then, in Section 4, we present our regression results, estimating the relationship between economic freedom and recycling rates in OECD countries from 2000 to 2019. Additionally, Section 4 details changes in recycling policies in the Republic of Korea and Taiwan as case studies to better understand the relationship between economic freedom and recycling policy. Section 5 discusses our results and potential avenues for future research.

2. Theoretical Background

The generation, disposal, and treatment of waste are all issues faced by developed and developing countries alike. As countries become richer, people consume more, leading to more waste generation. This trend shows no signs of stopping in the future; as countries become more developed, more waste is projected to be created [14]. Something must be done with that waste, and much of it is commonly relegated to landfills. Landfills and incineration facilities have been found to generate a variety of negative externalities, such as air pollution, greenhouse gas emissions, and water contamination, among many others [15–25]. These concerns have led to efforts to encourage recycling and reduce the volume of waste making its way to landfills. Although recycling programs have been commonly implemented through various government policies, such as mandatory recycling or subsidies, recycling can also emerge through private incentives.

Suppose we have an individual who we will call Maren. Maren consumes some good until its use value eventually reaches USD 0 (It is likely that Maren values the previously used good at some negative price, meaning she would be willing to pay someone to take the item. This item is then an economic bad, which is the opposite of an economic good. An economic good is something that individuals place a positive value on having a higher quantity. An economic bad, then, is something that individuals place a positive value on having a lower quantity. Waste is an economic bad. For simplicity, we assume the item's value is USD 0 in our example). At that point, from Maren's perspective, the good turns into waste and will be disposed of. However, the fact that Maren now values the good at USD 0 does not imply there is no other individual who places a value above USD 0 on what is now considered waste. If there is another individual, we will call him Lee, who values Maren's waste at USD 5 because he can convert it into a usable material, then there is the possibility for gains from trade between Lee and Maren. Lee is willing to pay up to USD 5 for the waste and Maren is willing to accept any price above USD 0. Maren and Lee can exchange at some price between USD 0.01 and USD 5 and both parties will be made better off. The differences in valuations of what Maren considers waste lead to opportunities for trade, creating the incentives for individuals to recycle. In a zero transaction costs world, Maren would be able to sell any of her waste to someone such as Lee, who is willing to pay for it (attaches some positive value to her waste). However, in a world with positive transaction costs, the costs of exchanging may prevent these transactions from occurring, as the ability for Lee to profitably find and collect these items may be costlier than the profit he would make from using, or recycling, them.

The higher a person such as Lee values the good, the more likely these trades will occur. However, the higher the transaction costs, the less likely these trades will occur. The magnitude of these transaction costs will be a function of the institutions under which these individuals exchange in. Under institutions with poorly defined property rights and significantly costly barriers to entrepreneurial action, transactions costs will be higher, leading to less transactions like the one between Maren and Lee. Countries with these institutions tend to be less economically free, as defined by the Economic Freedom Index [26], than countries with well-defined property rights and few barriers to

entrepreneurial action. In contrast, more economically free countries will tend to have stronger property rights and lower transaction costs, making it more likely for private exchange in recycling to emerge, *ceteris paribus*.

Even in a country with high economic freedom and significantly low transaction costs, there will always be some waste that cannot be profitably bought and used in a production process by an entrepreneur or consumed by someone with a positive consumer surplus. In such cases, negative externalities associated with waste disposal will still exist. Panel (a) in Figure 1 portrays this externality in the market for landfill services with a marginal social cost curve (MSC) having a higher price for a given quantity of landfill services relative to the marginal private cost curve (MPC). The societal optimal quantity of landfill services (Q^*) is less than the market equilibrium quantity (Q_e). There are several possible remedies.

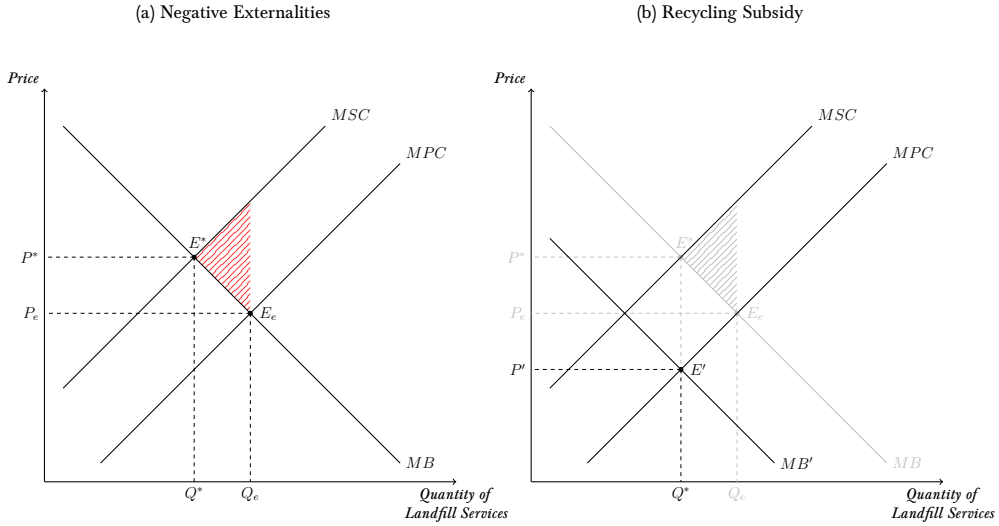

Figure 1. The market for landfill services.

The first-best solution would be to better define property rights to internalize the externality, as recognized by Coase [27]. However, there are high transaction costs associated with defining property rights over the relevant margins to internalize the externality, such as the externalities methane emissions have on air quality and changing the environment. The next best solution would be to institute a Pigouvian Tax on landfill services to the point where marginal private cost equals marginal social cost, thereby leading to an equilibrium quantity of (Q^*) (Numerous studies have analyzed the effects taxes have on waste [28–30]. For a discussion and economic analysis of the optimal waste tax, see Kinnaman [31]). As the price of landfill services increases with the tax, individuals will consume less landfill services. Although this leads to less waste being thrown into landfills, that waste may be placed in less desirable places through illegal waste-dumping activity. The unintended consequence to rising prices in landfill services is individuals engaging more in throwing their waste on public lands or even other people's property, as this type of disposal, although illegal, is a substitute for paying waste service fees (Multiple studies find that increasing waste taxes lead to increased illegal waste dumping [32–39]. Perhaps the most thorough investigation of illegal waste dumping, or "fly-tipping" as it is called in England, is Liu et al. [37]).

An alternative solution to a tax, and a common policy in many countries, is to subsidize recycling services. Recycling is a substitute for landfill services. A subsidy lowers the relative price of recycling to landfill services, leading to more waste being recycled and less thrown into landfills (For recent studies comparing waste taxation and recycling subsidy regimes, see Helm et al. [40] and Hua et al. [41]). The effect a recycling subsidy has on the market for landfills is shown in Panel (b) of Figure 1. The demand, or marginal benefit, for

landfill services falls because the price of recycling has fallen with the subsidy. The new equilibrium is at E' (Although the socially optimal quantity from the original graph in Panel (a) is reached, this is not the new socially optimal quantity with the subsidy included). Even though there still exists dead-weight loss in this market because $MPC \neq MSC$, the quantity is the same as that reached at equilibrium E^*, the intersection of MB and MSC. Through the subsidy for recycling, the original optimal quantity of landfill services in the market without the subsidy is reached (For a similar analysis on the economics of recycling subsidies, see [42] (pp. 486–487)).

There are multiple ways a government could subsidize recycling services. On one end of the spectrum, the government could pay private market actors the subsidy for recycling a certain quantity of waste. Alternatively, on the other end of the spectrum, the government could create a nationalized recycling industry where all recycling services are conducted by the state (Policies could fall between these two ends. For instance, government services may collect recycling waste and transport it to private recycling producers who they contract with. Or, some items could be recycled in the market while others relegated to government recycling facilities). The efficiency of recycling will depend upon which end the policy falls. There are three main reasons why we might expect a private recycling industry to be more efficient than a nationalized industry. First, private firms will have stronger incentives to reduce the cost of their services relative to bureaus. Second, private entrepreneurs will have more incentive to innovate recycling technology that will make the recycling process more efficient. Finally, the government faces a knowledge problem when trying to centrally plan the recycling industry.

Private entrepreneurs and bureaucrats operate in different institutions under different incentive structures (See Hazlett and Reilly [43] for a discussion of how entrepreneurial action differs in the marketplace and bureaucracy). Firms seek to maximize profit by producing the most demanded goods and services at the lowest cost. Thus, firms will actively seek to minimize the cost of production to reap larger profits. Since bureaucrats do not internalize the cost of producing their output, cost minimization incentives are weaker. For the bureaucrat, reducing costs will not increase net benefits unless budget increases are tied to cost effectiveness. When it comes to the production process, private firms stand to gain large profits if they can improve the efficiency of their production processes through innovation. Alternatively, the bureaucrats face disincentives for increasing the efficiency of their production processes. If a bureau produces the same output with less resources than before, it is in their political sponsors', the politicians who directly support the bureau, interests to allocate less budgetary funds to that bureau. As far as bureaucrats are interested in maintaining their job and salaries, they will seek to avoid such action (Bureaus have often been modeled as budget maximizing agencies [44]. If this is the case, then bureaus may face incentives to be less efficient in their production process as a strategy to increase their budgets).

Even if the government is able to overcome the hurdles of bureaucracy outlined above, they still face a knowledge problem with having to allocate resources in the nationalized industry. They would have to know the best location for recycling centers and the optimal size of each facility. Since not all waste is the same and some is easier to recycle than others, the government must decide which types of waste should be recycled. Finally, central planners would need to be able to effectively evaluate and innovate the recycling process. In a market for recycling services, this knowledge comes to fruition through the competitive market process. Firms in the wrong location, too small to take advantage of economies of scale, or too big to handle diseconomies of scale, will shut down. When waste cannot be profitability recycled, it will not be recycled at all. Entrepreneurs alert to profit opportunities will incessantly be searching for profitable recycling opportunities. Those who adopt the most cost-effective production techniques and technology will succeed, while those failing to do so will exit the market. Ultimately, there are mechanisms built into the the market process to find solutions to these problems, which will prove increasingly difficult for central planners to solve.

We have discussed three main reasons why free markets and private industry may lead to better recycling outcomes than a regulated or nationalized industry in recycling. Exchanges which could divert waste from landfills are more likely to happen in more economically free countries with less barriers to entrepreneurial action and voluntary exchange. Even if the desired level of recycling is not brought about through private recycling efforts, a subsidizing private industry is likely to have better recycling outcomes because private actors will seek to lower the production costs of recycling and will constantly seek more efficient recycling methods (The production costs of recycling do not only have economic effects, but also environmental effects. The fewer resources and energy used to recycle, the lower the carbon footprint of the recycling process, see Soltanian et al. [14] for a discussion of some of these effects). Additionally, when recycling is the responsibility of a government agency, there will be greater opportunities for mission creep and the growth of the bureau in other areas. Knowledge problems will be mitigated in the market through competition and profit and loss signals.

3. Methodology

3.1. Data Description

The variables for our econometric analysis are collected from the Fraser Institute [45] and the OECD Stat database [46]. Brief descriptions and sources for all variables can be found in Table 1. What follows is a more detailed description of the data set.

Table 1. Variables and data sources.

Variable	Source	Definition
Economic Freedom of the World Index	Gwartney et al. [45]	Index value ranging from 0 to 10, measuring the level of economic freedom in a country-year.
Recycling Rate	OECD [46]	Percentage, from 0 to 100, of waste diverted from waste streams for recycling (i.e., reprocessing of material) in a given country-year.
Material Footprint Per Capita	OECD [47]	Volume of raw material extracted to meet the final demand of an economy in thousands of kilograms in a given country-year.
Environmental Taxes	OECD [48]	Tax revenue generated by environmental policies as a percentage of total tax revenue in a given country-year.
Environmental Policy Stringency Index	OECD [49]	Level of environmental policy stringency, ranging from 0 to 6, in a given country-year.
GDP Per Head	OECD [50]	GDP per head in 2015 USD constant prices and constant PPP in a given country-year.

We collect data on a panel of 33 OECD countries and Brazil from 2000 to 2019 (Ideally, we would have complete data on all OECD countries. Colombia, Costa Rica, Latvia, Lithuania, and New Zealand do not have complete data available across our sources and are omitted). The empirical analysis in this paper is limited to OECD countries due to data availability issues. While the Economic Freedom of the World (see full description below) has data on many more countries, other variables including those on recycling rates and environmental policy used below are only available for OECD countries. Our results, then, should be interpreted with some caution, as we do not claim the results are applicable outside of our sample (e.g., countries on the continent of Africa). The full data set is unbalanced, with some countries having as few as one year of data for all variables. Our analysis uses both the unbalanced panel and the balanced panel after dropping any country that does not have data in every year from 2000 to 2019. The balanced panel contains 16 OECD countries from 2000 to 2019. The list of countries in our data set and the number of years they appear are reported in Table 2. Below is a description of the variables we use in our regression analysis.

Table 2. Countries and number of years available in full panel from 2000 to 2019.

Country	Years	Country	Years
Australia	14	Italy	20
Austria	20	Japan	20
Belgium	20	Korea, Rep.	13
Brazil	1	Luxembourg	13
Canada	8	Mexico	11
Chile	5	Netherlands	20
Czech Republic	20	Norway	19
Denmark	20	Poland	20
Estonia	6	Portugal	16
Finland	20	Slovak Republic	14
France	20	Slovenia	11
Germany	20	Spain	20
Greece	12	Sweden	20
Hungary	20	Switzerland	20
Iceland	2	Turkey	4
Ireland	16	United Kingdom	20
Israel	6	United States	19

To analyze the relationship between economic freedom and recycling rates, we use the Economic Freedom of the World Index constructed by the Fraser Institute [45]. The index is internationally comparable and captures economic freedom based on five key areas that are summarized in the index value appearing in our regressions. The five areas include the size of government, legal system and property rights, sound money, freedom to trade internationally, and regulation [26]. Each of these five areas has several sub-components that are inputs to the summary index value. Yearly summary index values are restricted to the years from 2000 to 2019 to match the data from the OECD stat. The summary index ranges in value from 0 to 10, where 0 represents the lowest level of economic freedom and 10 represents the highest level of economic freedom. We restrict the countries from this data set to those matched with the OECD data described below.

The dependent variable in our regressions is the recycling rate collected from the OECD stat [46]. This variable measures the percentage of waste that is diverted from waste streams for recycling. Waste as captured in this measure includes household and similar waste, such as that generated by small businesses, office buildings, and institutions. Recycling is defined in the OECD database as follows:

> any reprocessing of material in a production process that diverts it from the waste stream, except reuse as fuel. Both reprocessing as the same type of product and for different purposes are included. Direct recycling within industrial plants at the place of generation is excluded.

The control variables in our regressions are also collected from the OECD stat database. The first is GDP per head in 2015 USD constant prices and constant PPP [50]. Our intention with this control is to hold constant any wealth effects that may influence the recycling rate within countries over time. Although it is likely that including the GDP measure quadratically is most appropriate to capture any Kuznets-type relationship, we are unable to do so given our dataset. The matrices to estimate our regression coefficients are not invertible when squared GDP is included, we are limited to including GDP per head alone. The data on GDP ranges from USD 11,000 per head (Brazil) to over USD 114,000 per head (Luxembourg) and has a standard deviation over USD 15,000.

We have data on the material footprint per capita, which measures the volume of raw material (in thousands of kilograms) extracted to meet the final demand of an economy [47]. This measure may have a relationship with the production of waste and treatment through recycling not captured by our other control variables. Recycled materials and raw materials are to some degree substitutes in production. As a country recycles more, we would expect that raw material extraction will decline, holding all else constant.

Our final two variables are related to environmental policy and are included to capture policy effects that may be related to both economic freedom and recycling rates. The first

is environmental tax revenue as a percentage of total tax revenue [48]. In our sample, this variable ranges from −12.1 to 13.8, suggesting that in some countries environmental subsidies exceed environmental taxes on net. The second is the Environmental Policy Stringency (EPS) Index [49]. This is a country-specific and internationally comparable measure of environmental policy stringency bounded between 0 and 6, where 6 represents the highest level of stringency and 0 represents the lowest level of stringency. The average value of this index in our data is 2.7 though there is considerable variation across and within countries. For example, between 2000 and 2018, the EPS Index in the United States rose from 1.2 to 2.9, suggesting that environmental policy became substantially more stringent over this period.

Although the environmental taxes and the environmental policy stringency variables are related to environmental policy in general, we expect that these variables will have some relationship with recycling rates. Environmental policies may include taxes on waste or subsidies for recycling, both of which are likely to induce higher recycling rates, but the expected direction of the relationship between our environmental tax revenue variable and recycling rates is ambiguous. Increases in recycling subsidies will reduce this measure of environmental tax revenue, while increases in taxes on waste will increase it. Both changes may lead to increases in recycling rates. Regardless of the direction of the effects, including the measure of the environmental tax revenue and the EPS Index will aid in disentangling the effects of economic freedom directly and any potential induced policy response related to economic freedom [2]. Summary statistics for all our variables can be found in Table 3.

Table 3. Summary statistics.

Variable	N	Mean	St. Dev.	Min	Max
EFW Index	510	7.772	0.429	5.800	8.850
Recycling Rate	510	23.427	11.685	0.106	59.929
Material Footprint Per Capita	510	27.291	11.437	10.154	88.703
Environmental Taxes	510	6.863	2.391	−12.140	13.810
Environmental Policy Stringency Index	510	2.706	0.841	0.000	4.722
GDP Per Head (thousands)	510	42.058	15.548	11.421	114.805

Figure 2 shows a scatter plot of economic freedom values and recycling rates in a given country-year for our entire data set and the simple linear relationship between the two variables estimated using Ordinary Least Squares (OLS). There is a strong positive relationship, suggesting that more economic freedom may have a positive impact on recycling rates. However, this relationship may be due to other factors correlated with economic freedom, recycling rates, or both. We address this issue using the empirical strategy described in the following section.

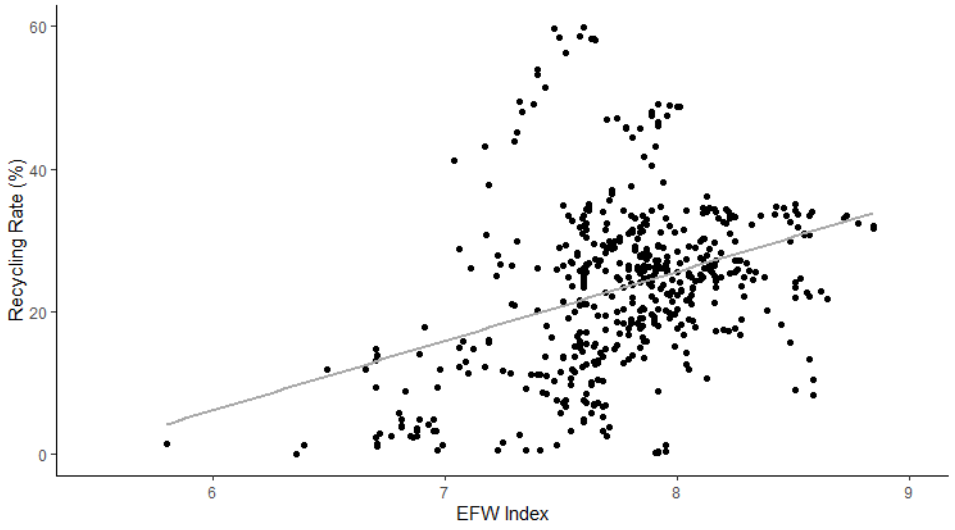

Figure 2. Economic freedom of the world index and recycling rates.

3.2. Empirical Strategy

Our strategy to obtain a better estimate of the relationship between economic freedom and recycling rates is to control for relevant factors, such as GDP and policy variables, and introduce time and country-specific fixed effects. In doing so, we can quantify the relationship between economic freedom and recycling rates independent of those relevant controls and any unobserved heterogeneity specific to a given year or country. The econometric model based on this strategy is given by the following equation:

$$Y_{i,t} = \beta_1 EFW_{i,t} + \mathbf{X_{i,t}}\mathbf{\Gamma} + \alpha_i + \alpha_t + \epsilon_{i,t}. \quad (1)$$

$Y_{i,t}$ is our outcome variable of interest, recycling rates which are bounded between 0 and 100. Recycling rates are bounded in this way because, in the extremes, either no waste is diverted to recycling or all waste is diverted to recycling given the definition of recycling rates. $EFW_{i,t}$ is economic freedom for country i in year t, and β_1 is our coefficient of interest. $\mathbf{X_{i,t}}$ represents a matrix of our control variables including GDP per capita, material footprint per capita, environmental tax revenue as a percentage of total tax revenue, and the environmental policy stringency index. $\mathbf{\Gamma}$ is a vector of regression coefficients for the control variables. Country and year fixed effects are given by α_i and α_t, respectively. Errors are given by $\epsilon_{i,t}$. We estimate this model using the full unbalanced panel of data and the balanced panel of data using a within-panel estimator and the "plm" package in the statistical software R. Standard errors are clustered at the country level and heteroskedasticity robust. The purpose of the two-way fixed effect approach here is to control for any unobservable characteristics that may be unique to a specific year or specific country as a way to isolate the relationship between economic freedom and recycling.

We test for misspecification using a Hausman test to ensure that the fixed effects model is appropriate in contrast to random effects using our base regression model with both country and year fixed effects against a model with the same controls and random effects instead of the original fixed effects. The null hypothesis of the Hausman test is that country specific errors are correlated with regressors. Failing to reject the null hypothesis would suggest that a random effects model is preferable to a fixed effects model. The results of this test strongly reject the null hypothesis, suggesting that our fixed effects specification is appropriate for this context. We also face the choice of whether to include year fixed effects. Two tests used to confirm year fixed effects are necessary. First is a Breusch–Pagan test, which is a Lagrange multiplier test on a model including county fixed effects alone, where the null hypothesis is that there are no significant time effects. Second is a simple partial F-test of models with and without year fixed effects where the null hypothesis is that there is no joint effect of year fixed effects. Failing to reject the null hypothesis in either of these tests would suggest that the year fixed effect may not be necessary. However, the results of both tests for the unbalanced and balanced panels suggest year fixed effects are necessary as the null hypotheses are strongly rejected. Therefore, our preferred specification is the two-way fixed effects regression with our set of controls that will estimate the effect of changes in economic freedom on recycling rates within the countries in our sample. The results for each of the specification tests are reported in Table 4 using both the unbalanced and balanced panels of data.

Table 4. Specification tests.

	(1) Hausman Test	(2) Breusch-Pagan Test	(3) Partial F-Test
Unbalanced Panel	50.69 ***	6.83 ***	3.32 ***
Balanced Panel	73.98 ***	5.83 **	2.64 ***

Note: ** $p < 0.05$; *** $p < 0.01$.

4. Findings

4.1. Regression Results

Our regression estimates using both unbalanced and balanced panels are reported in Table 5 where the control variables are those as described in Section 3.1 and both country and year fixed effects are included in both regressions. The first column of Table 5 shows the results for the unbalanced panel. In this estimation, economic freedom has a large and statistically significant effect on recycling rates. The standard deviation of economic freedom in the unbalanced panel is around 0.8, and our estimates suggest that a one standard deviation increase in economic freedom results in a nearly nine percentage point increase in recycling rates. This effect is equivalent to a 0.75 standard deviation increase in recycling rates. Compare this to the effect that an increase in environmental tax revenue has on recycling rates. A one standard deviation increase in environmental tax revenue (2.4 percentage points of total tax revenue) increases recycling rates by only 0.12 standard deviations. These results suggest that increases in economic freedom can have large effects on recycling rates independent of direct environmental policy effects. This is not to say that policies targeting recycling are unimportant. Rather, increases in economic freedom can create the conditions that make it in people's interest to recycle more. Although the exact mechanism(s) cannot be determined by our results, it is likely that increases in economic freedom through changes such as stronger property rights give people the ability to capture the value of turning waste into recycled materials. A further limitation of these results is that we cannot be sure we are estimating a causal effect. The fixed effects and controls do help isolate the effect of economic freedom on recycling rates, but there are likely other omitted variables that prohibit us from properly identifying the causal effect. For example, we do not have data on a recycling-specific environmental policy that would be associated with recycling rates and be possible with economic freedom. The omission of such a variable introduces the potential of bias in our estimates. While we are confident that the included fix effects help to address this issue, a causal interpretation of our estimates should be avoided.

Table 5. The effect of economic freedom on recycling rates.

	Dependent Variable: Recycling Rate	
	(1) **Unbalanced Panel Results**	**(2)** **Balanced Panel Results**
EFW Index	10.996 ***	13.745 ***
	(1.431)	(1.891)
GDP Per Head (thousands)	−0.054	−0.161
	(0.083)	(0.185)
Material Footprint Per Capita	−0.020	−0.043
	(0.046)	(0.105)
Environmental Tax Revenue	0.604 ***	1.672 ***
	(0.160)	(0.343)
Environmental Policy Stringency	0.667	0.022
	(0.616)	(0.704)
Observations	510	320
R^2	0.170	0.258

Note: *** $p < 0.01$.

Similar results hold for the estimates using the balanced panel reported in the second column of Table 5. The section that follows will discuss two case studies to further touch on potential mechanisms and causal evidence for the results found here by focusing on the interactions between recycling policies and outcomes associated with economic freedom.

4.2. Case Studies

In recent years, the Republic of Korea and Taiwan have become two of the only non-European countries to enter the ranks of the world's top recyclers. As East Asian countries, the Republic of Korea and Taiwan have had different development paths from their Eu-

ropean counterparts, making them interesting cases to examine recycling under different policy regimes. While both countries rely on subsidies to spur recycling, the Republic of Korea utilizes a private market for recycling industry while Taiwan has transitioned from private recycling to nationalized recycling centers.

4.2.1. The Republic of Korea

In 2018, the Republic of Korea became the only non-European country to rank in the top-five leading recyclers in the world [51], and had the highest recycling rate of the year, 61.57% [46]. This is a new trend for the nation, with their recycling rate more than doubling since 1994 [52]. The Republic of Korea's unique waste management system may shed light on this phenomenon. The Republic of Korea's modern waste management system is neither completely public nor private and developed very rapidly after a series of major policy changes beginning in the late 1980s. The defining feature of these policy changes was a change in the assignment of property rights over recycling management.

From the end of the Korean War to the early 1990s, waste in the Republic of Korea was managed under a public regime [53]. During this period, the cost of waste management was negligible to both households and firms. Because the Korean War virtually decimated all industry in the Republic of Korea, very little waste was generated in the Republic of Korea in the early years of its existence [53]. However, industry in the Republic of Korea rapidly developed and large-scale waste was being produced by the late 1970s. Until 1993, all waste created from the entirety of the Seoul metropolitan area and surrounding rural areas was collected by the municipal governments and dumped in the Nanji landfill [52,53]. In the late 1980s, the Korean government began to notice that the Nanji landfill would soon reach capacity [52,53]. Not only was the site running out of space for dumping, but Seoul citizens were beginning to raise health concerns regarding the pollution resulting from the decaying mountain of garbage and waste incineration [52–54]. The government initially proposed building a multitude of new landfill sites around Seoul; however, these plans received severe public backlash. Similar to NIMBY attitudes towards multi-family housing, many residents of Seoul and surrounding areas strongly opposed the construction of a landfill near their community. The federal government responded by passing the Waste Control Act of 1986.

The aim of the Waste Control Act was to reset the framework for waste management and prepare the Republic of Korea for the policy changes that would follow it [52,53,55,56]. The Republic of Korea uses a hierarchical structure for its waste management policy agenda. Before the Waste Control Act, incineration and landfill were at the top of the policy hierarchy, followed by waste reduction and utilization [52,53,55]. The Waste Control Act flipped the policy agenda such that reduction and utilization were at the top and landfill and incineration were pushed to the bottom. This shift allowed for a stream of policies to be passed over the course of the following decade with the intent of reducing municipal waste and rebuilding the waste management system. Of these policies, three made the most significant difference in waste management practices. Two of these policies were targeted towards producer waste and one policy was targeted towards household waste. The first of the producer-focused policies, the Deposit Refund System (DRS) enacted in 1993, was aimed at spurring recycling practices in producers of designated recyclable outputs. Second, the Extended Producer Responsibility (EPR) system of 2003 replaced the DRS. In order to address household waste, the implementation of the Volume-based Waste Fee (VWF) system in 1995 made households bear the cost of their waste for the first time [52–55].

The DRS and EPR policies targeted producer responsibility over waste. The DRS policy created a system in which producers of designated outputs were given the option to either pay the municipal government a fee to dispose of their waste via landfill or incineration, or they could recycle their waste and receive a refund for the disposal cost [52,53,55]. This fee was referred to as the "deposit rate" and was a rate of Won per kilogram set by policymakers that varied by industry. The deposit rate was the price at which producers would pay

to have their waste deposited in a landfill by the government, or on the flip-side, what producers would be refunded if they recycled their waste. Effectively, the government was attempting to make producers bear more of the cost of their waste while simultaneously subsidizing recycling. Prior to the enactment of DRS, Korea lacked recycling infrastructure and there was no private industry for recycling. At the time of implementation, many firms in industries where recycling costs of their products were relatively low, such as tires, glass, lubricants, and batteries, quickly developed recycling infrastructure to reap the benefits of the refund. Shortly after the implementation of DRS, demand for both private recycling facilities and recycled products grew, resulting in a quickly developing private recycling industry. Several producers even built recycling facilities that offered nation-wide recycling services.

Some industries opposed DRS in its early years. These industries mainly consisted of producers of durable goods, such as home appliances, and other products that were very costly to recycle. They argued that the lack of recycling infrastructure made it impossible to recycle their waste and they were unable to receive the refund other industries benefited from. As the recycling sector developed, some of these industries that initially resisted DRS began to invest in recycling innovation and partake in recycling to receive the refunds.Over the course of the DRS era, the ratio of refund to deposits steadily increased. The refund-to-deposit ratio was two percent in its first year, but reached fifty-two percent after a decade [53] (p. 4).

The EPR system had the same goal as the DRS: make producers responsible for their waste. The methods of achieving this goal, however, were very different. Under the new system, the government discarded the refund mechanism to incentivize producers to recycle and instead requires producers to recycle a specific percentage of their waste each year. The required rate of recycling is gradually increased over time. The EPR system is still in place today and regulates the production of 24 products [53] (p. 7). The EPR system faced virtually no resistance from the affected industries. By the time of the implementation of EPR, there was a robust private sector for recycling and recycled products in the Republic of Korea, as mentioned before. The development of this sector, thanks to DRS, made the transition to EPR very smooth. Because a certain rate of recycling is required under EPR, all regulated industries meet this requirement and the program is viewed as a success. Due to this command-and-control program, the industries that were recycling at very low levels under DRS were forced to reach the new recycling requirements; however, there has been no change in behavior of firms that began recycling in the 1990s.

4.2.2. Taiwan

Similar to the Republic of Korea, Taiwan emerged as an East Asian leader in recycling in recent years. Since 2019, Taiwan has maintained a recycling rate of about 56%, the world's second highest behind Germany. While they both climbed the ranks of "sustainable" countries in the past few decades, the Republic of Korea and Taiwan have had fairly different policy approaches to waste management. Taiwan provides a case where a once fully private market for recycling was crowded out by a central authority. Beginning in 1989, the federal government of Taiwan began a four-stage system to move recycling in the country from the private market to a more nationalized industry [57,58].

The aim of the four-stage system was to slowly transition recycling from private to public over time as the EPA, a budget-maximizing bureau, exhibited mission creep. The first stage, which lasted from 1989 to 1994, primarily involved identifying 17 items that would be regulated to be recycled and determining and implementing these regulations. These regulations were suggested by special committees whose members consisted of leaders in the industries of the regulated items. In addition, the Taiwan EPA set annual mandated recycling rates for each regulated item and monitored the relevant industries.

Stage 2 of the program lasted from 1994 to 1996. During this phase, the government began to increase involvement in the recycling industry. During Stage 1, the government faced many issues with monitoring the recycling industry, such as lack of transparency and false

data reporting. To solve these issues, they established the Reduction, Recycling, and Reuse Foundation (3R Foundation), a non-profit government organization [57]. The aim of the 3R Foundation was to obtain contracts with the regulated industries that would give them the rights to take over recycling their products. They were successful on this front with the vehicle industry and handled recycling abandoned vehicles through their own shredding plant. However, 3R was unsuccessful at obtaining contracts with other industries.

Stage 3 was very short but very significant. From 1997–1998, Taiwan's Environmental Protection Administration (EPA) overhauled the entire recycling industry by establishing eight "recycling fund" committees to manage the entire industry. The committee members were selected by the EPA, their funds were public, and their budgets required EPA approval. Initially, the committees were overseen by the EPA but operated independently, similarly to a central bank.

In Stage 4 of the system, which was implemented in 1998 and persists today, the committees were fully centralized under the EPA. From the changes made during Stage 4, 28 items faced mandatory recycling programs and were required to pay fees for this recycling to the Resource Recycling Fund Management Committee, a new layer of bureaucracy that was responsible for overseeing and managing the eight recycling fund committees. The Resource Recycling Fund Management Committee is then overseen by parliament. These changes have resulted in a highly regulated system for recycling. Producers and importers of regulated items are required to register with the EPA and must pay a fee and have their items recycled at their end-of-life. The funds from the fees paid are collected and managed by the recycling fund committees. Most of the funds are allocated towards subsidies to the industries that are mandated to recycle; however, the EPA is able to use these funds for essentially anything they deem fit.

The four-stage system was highly effective in propelling Taiwan to a top recycling rate, and Taiwan's EPA is continuously praised for policy success. However, there are a number of studies showing the achievement of this recycling rate is accompanied by a myriad of flaws. Some studies have questioned the efficiency of the state-sponsored recycling operations. Chen et al. [59] (p. 1667) assess the effects of the policy regime in the end-of-life vehicle recycling market. Prior to the policy change, there was a robust private market for the secondary recycled parts of vehicles, such as batteries and engine parts, as these scraps are valuable resources. The authors find that the nationalized recycling operators lack sufficient focus on auto shredding residue pollution, it is unclear whether the recycling fee will stimulate green innovation from producers, the Recycling Fund Management Committee shuts down illegal recycling operations that account for a significant amount of end-of-life vehicle recycling, and many of the recycling operations have very high energy costs that are not considered when assessing their environmental impact.

Hsu and Kuo [60] note that recycling operators of home appliances are almost entirely supported by federal funds, and it is highly questionable whether these operations are cost-effective. Shih [61] discusses two weakness of the policy regime in the context of E-waste recycling: the policy eliminates competition between recyclers, and the imposed recycling standards have very high monitoring costs. Similarly, Chang [62] argues that some policy changes need to occur to promote more competition in the recycling of scrap tires. Wen et al. [63] question the ability of EPA performance indicators to accurately assess recycling performance. While this handful of studies assesses industry-specific problems, there is clearly a pattern in the recycling regime.

A high recycling rate achieved through nationalization seems to come at the cost of competition between recycling operators, lags in technological innovation, increased monitoring, and unclear performance assessments, all typical benefits of the private market. The root of these issues with the current regime stems from the fact that the Taiwan EPA faces the planners problem. The Recycling Fund Management Committees do not have complete knowledge in order to efficiently allocate funds, calculate the optimal recycling rate, organize operators, etc. One overarching issue with the efficiency of the regime identified by Ye et al. [64] is the number and location of recycling centers. Ye et al. [64]

suggest that there are currently too many recycling centers and that these centers are too far from many collection depots. It might be more efficient to reduce the number of centers and relocate them closer to collection depots. If the profit–loss mechanism was more prevalent for recycling operators, these types of issues would be mitigated much more efficiently. Similarly, Lee and Na [65] note that the majority of recycling in Korea is performed by small- to medium-sized private operators, whereas in Taiwan the only legitimate operators are the large state-sponsored centers. Because of this, producers in the Republic of Korea provide more support, communication, and information to recycling operators, whereas in Taiwan the producers are relatively disconnected from the recycling centers. Tsai et al. [66] also discuss some regulatory issues of the system, such as vague regulatory definitions. It is impossible for the EPA and subsequent Recycling Fund Management Committees to evade these issues as the government mechanism necessarily faces a knowledge problem. Overall, it is unclear whether the benefits from reaching the 56% recycling rate outweigh these costs.

5. Discussion

Can markets improve recycling performance? If transaction costs are high from economically restrictive state regimes, then recycling is less likely to occur. Alternatively, under more economically free institutions, entrepreneurs will be more able to seize profit opportunities from converting waste to economic goods. This is supported by the findings of this study. The regression results in Section 4.1 showed a relationship between economically free countries and higher recycling rates. Although we cannot be certain of the exact mechanism causing the correlation from our empirical findings, the case studies of countries who relied more on private industry, a prominent organizational feature of economically free countries, tend to have more efficient recycling processes. These results suggest that if countries are concerned with increasing their recycling rates and the efficiency of their recycling industry, they can do so by increasing economic freedom. Economically free institutions allow entrepreneurs to profit more from converting waste to something of value. This paper bridges the gap between the literature on the relationship between institution and environmental problems and on the economics of recycling. We show how institutions that promote entrepreneurship through economic liberalism can increase recycling rates and efficiency.

However, even in the most economically free country, the private recycling market may not be able to lower the negative externalities associated with landfills to desirable levels. In this situation, subsidizing private recycling industry will lead to lower costs of recycling and more innovation in recycling technology than nationalized recycling bureaus. However, a major problem with subsidizing recycling is knowing the optimal subsidy or desired recycling level. Too small of a subsidy may not offset the negative externalities from landfills to the desired level while too large of a subsidy may divert too many resources to the recycling industry. Government planners would need to compare not just the accounting costs, but the economic opportunity costs, of the following possible regimes: (1) waste tax, (2) recycling subsidy, (3) no intervention, and (4) some combination of these policies. Each regime has its own costs. An effective waste tax requires the enforcement of illegal dumping laws, which entails high monitoring costs. Recycling industries use valuable resources in labor and capital with significant economic opportunity costs. Additionally, the recycling industry may pose its own negative externalities on the environment (Recycling can negatively impact the environment through "the collection, sorting, and processing of materials into new products" and thus, "it is unclear when recycling is to be preferred to the use of virgin goods or when waste recovery should replace landfilling or incineration" [42] (p. 482)). Without intervention, landfills pose significant negative externalities from air pollution that are not fully internalized by private owners. It may be extremely difficult, if not impossible, to compare these solutions to landfill externalities.

For example, although the DRS in the Republic of Korea was instrumental in establishing a private recycling sector, it was plagued by these issues. The main flaw of the

DRS was the deposit rate. This rate was set by the Ministry of Environment, a federal government bureau. Because this rate was set by central planners, it was impossible for it to accurately reflect the true cost of recycling. The central planners were "groping in the dark" [67] (p. 110) and essentially guessing at what rate would result in the "optimal" level of recycling. While the DRS made producers face at least some of the cost of their waste for the first time, the knowledge problem associated with the government setting the deposit rate made the system unsustainable. For the final few years of the program, the refund-to-deposit ratio hovered around 50 percent. This stagnation is easily explained. While some industries were able to reach refund-to-deposit ratios of 100 percent, others did not crack a 10 percent ratio. This is because it was impossible for policymakers to set a deposit rate that accurately reflected the cost of waste management across all industries. For many industries, the deposit rate was never high enough to incentivize them to recycle. There was flexibility under DRS that made it possible for producers to recycle in a cost-effective manner. While this feature of DRS allowed private industries to determine the rate of recycling that was best for them, the government saw this as sub-optimal. After a decade, the federal government discarded DRS and replaced it in 2003 with the EPR system, further exacerbating the knowledge problem.

One way to approach these dilemmas is through polycentric governance. We can think of the provision of waste management services as a public service industry. Work from Ostrom [68] shows the advantages of a polycentric approach to public service provision. Top-down monocentric policies may not fully account for the important geographic details and tacit knowledge of community actors. Enforcing illegal dumping laws or creating recycling opportunities for private actors may be better handled at local levels. Alternatively, some communities may completely ignore their negative externalities from landfills, or ship their waste to foreign landfills while other communities take too costly of actions to reduce their landfill waste. Some combination of policy set at the federal and local levels and various nodes of private and public governance may be the optimal way to tackle these difficulties.

The findings in this paper present opportunities for future work to further explore alternative paths to recycling and other waste management policies. As noted in the discussion of the results, a key limitation of our regression estimates is the inability to determine the exact mechanisms by which economic freedom is positively associated with increases in recycling rates. We speculate that property rights specifically play an important role here; however, more research is needed to test the validity of that hypothesis among other potential mechanisms. Alternative research designs focusing on specific policy changes may also be more fruitful in recovering causal estimates of the effects economic freedom has on recycling rates. The case study approach to outlining the differences between private industry versus government management of recycling also has limitations. While we do compare two relatively similar countries, more data is needed to have more general evidence of the substantive differences in efficiency between recycling management institutions. There is a sound theoretical basis for the inefficiencies related to bureaucratic management, but the size of those inefficiencies is inherently an empirical question that can be answered with more data. Significant variation in waste management policies, even within individual countries, presents an opportunity to begin establishing better estimates of those inefficiencies. Furthermore, a limitation of our analysis is that it relies only on the economic theory underlying recycling policy. Additional complementary research is needed to assess the sustainability of various recycling policy schemes, such as those carried out for refinery systems [69].

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Abbreviations

The following abbreviations are used in this manuscript:

OECD	Organization for Economic Cooperation and Development
USD	United States Dollars
MSC	Marginal Social Cost
MPC	Marginal Private Cost
MB	Marginal Benefit
EFW	Economic Freedom of the World
PPP	Purchasing Power Parity
GDP	Gross Domest Product
EPS	Environmental Policy Stringency
DRS	Deposit Refund System
VWF	Volume-based Waste Fee
EPR	Extended Producer Responsibility
EPA	Environmental Protection Administration

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