Dynamic Spillover between the Chinese and International Wastepaper Markets: Analysis of the Impact from China's Newly Implemented Wastepaper Policies

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Abstract

As China is the largest importer of wastepaper in the world and is highly dependent on the international market, the relationship between the Chinese and international wastepaper markets affects the stability of both markets. The purpose of this study was to investigate the impact of China's newly implemented wastepaper polices on the degree of integration between the Chinese and international wastepaper markets and analyze the dynamics of the relationship between the two markets over time. We developed both the static and dynamic total spillover indices to analyze the degree of integration in average and in time-varying perspectives and performed E-Divisive with Medians (EDM) on the dynamic total spillover index to evaluate the impacts of the new policies. The results revealed that the Chinese and international wastepaper markets were integrated. The calculated dynamic total spillover index varied widely during the studied period and presented an overall declining trend, indicating that these policies have disrupted the integration relationship between the two markets. The results of EDM detected structural breaks in the dynamic spillover index due to the new policies, further confirming and describing the negative impacts of the new policies on the integration relationship between the two markets. Since mutual dependence exists between the Chinese and international wastepaper markets, the interventions on the integration relationship have led to dramatic fluctuations and expanding price differences between the two markets, imposing risks and uncertainties on the stable development of China's paper industry and the global recycling industry.

With the development of China's economy, the consumption and production of paper products in China has continued to increase. China has become the world's largest consumer and producer of paper and paperboard (Chen et al. 2018). The production and consumption of paper and paperboard reached 104.35 and 102.92 million tons, respectively, in 2018 (Food and Agriculture Organization of the United Nations [FAO] 2019). Since forest resources are scarce in China, recycled pulp has become the dominant fiber material for China's paper industry (see Fig. 1a). The demand for recycled pulp in the Chinese market keeps rising, but the domestic recycling capacity and the wastepaper quality cannot meet the needs of China's paper industry (Yin et al. 2008). Shen et al. (2019) indicated that China's wastepaper recycling capacity has approximately reached its ceiling because of limited domestic paper product consumption and a decreasing amount of recyclable paper products. The estimated maximum possible volume of wastepaper recovery in China is 58 million tons, but domestic wastepaper consumption exceeded 75 million tons in recent years. Because of the limited domestic supply capacity, China is highly dependent on the international wastepaper market and imports large amounts of wastepaper every year (see Fig. 1b). In 2016, the import volume of wastepaper reached 28.50 million tons, accounting for 36.48

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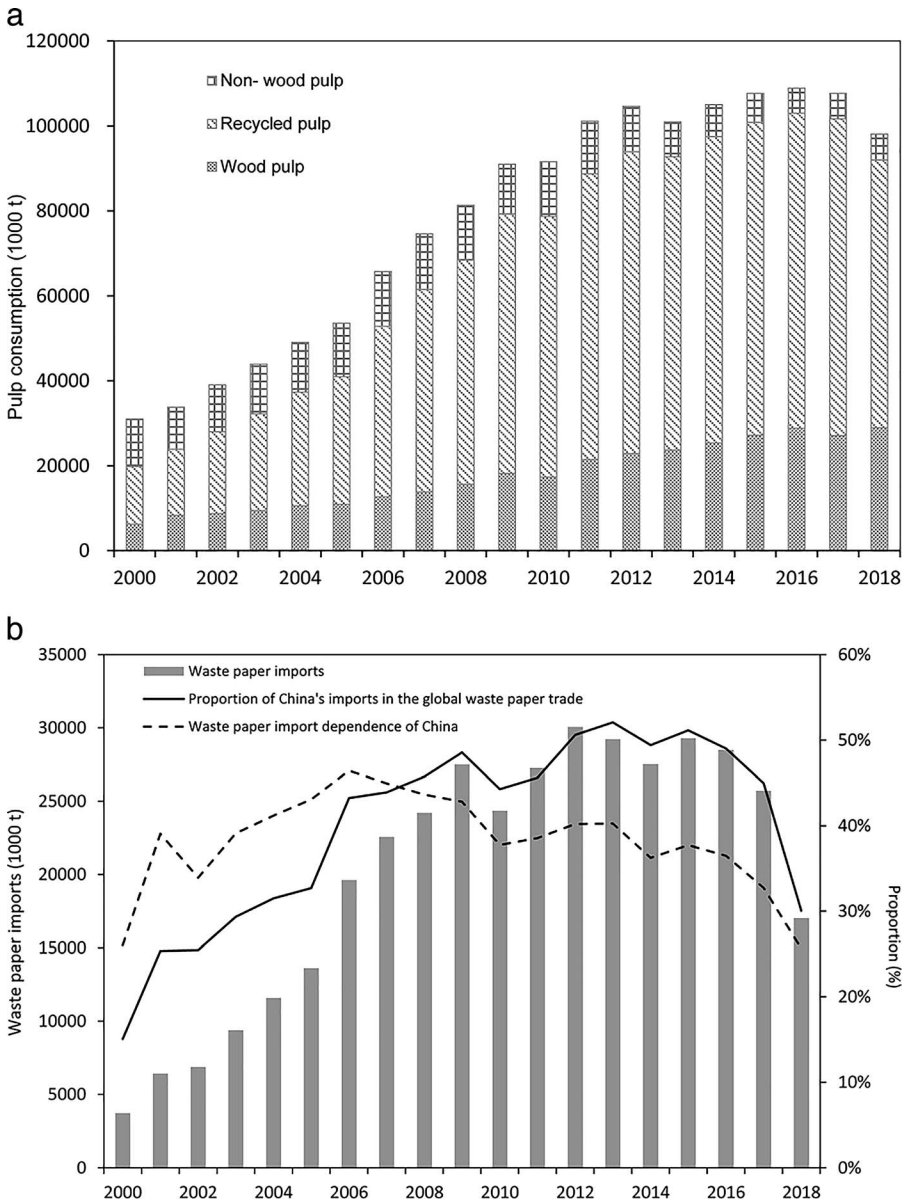

Figure 1.—China's (a) pulp consumption and (b) wastepaper imports.

percent of the total wastepaper consumption. With nearly half of global wastepaper exports destined for China in recent years, China has become the largest importer of wastepaper and plays a crucial role in the international wastepaper trade (see Fig. 1b). The mutual dependence and close interactions between the Chinese and international wastepaper markets make the two markets integrated.

With increasing amounts of wastepaper sent to China, a large sum of unusable wastes, even dangerous wastes, also enters China and ends up in landfills or incinerators. Environmental and health considerations have led the Chinese government to enforce stricter policies on the import of wastepaper (see Table 1). These policies aim to mitigate the negative impacts from wastepaper imports by strengthening customs inspections and requiring a low level of contamination in imported wastepaper. Affected by the new policies, the import volume of wastepaper in China dropped dramatically, breaking the balance between the Chinese and international wastepaper markets and causing fluctuations in both markets. Since 2017, growing price differences have occurred between the Chinese and international wastepaper markets, with a sharp price increase in the Chinese market and a dramatic price decrease in the international market. In the Chinese market, the domestic prices of both wastepaper and wood pulp have jumped more than 30 percent (Stanley 2019, Wang 2019). Furthermore, although the prices of wastepaper and wood pulp rose sharply, margins of the papermaking enterprises have eroded because of soaring costs of materials. This will lead to either increases in paper product prices or mill closures, which may then affect the pulp suppliers and other related parties in China's paper industry.

With regard to the international wastepaper market, the new policies pose a risk to the wastepaper recycling industry. On the one hand, the sharp decline in China's wastepaper imports made for supply surplus in the international wastepaper market and led to a plunge in wastepaper price (FAO 2019). On the other hand, the cost to

Table 1.—New policies on wastepaper in recent years.

Title of policy	Issue date	Implementation date	Specification
Operation Green Fence	—	Feb 1–Nov 30, 2013	Contamination rate of 1.5% enforced for wastepaper import; stricter inspections on incoming containers loaded with recyclables; penalties strengthened for foreign garbage smuggling
Catalogue of imported waste management	Dec 30, 2014	Jan 1, 2015	Wastepaper listed in ''Catalogue of solid waste used as raw materials under restricted import"
Comprehensive utilization of resources and labor value-added tax (VAT) preferential directory	Jun 12, 2015	Jul 1, 2015	A rebate of 50% on the VAT paid by pulp and paper producers on their recycled-based products
Implementation plan for prohibiting the entry of foreign garbage and advancing the reform of the solid waste import administration system	Jul 27, 2017	Jul 27, 2017	Unsorted wastepaper banned from import; penalties strengthened for foreign garbage smuggling; stricter control on the issuance and use of solid waste import licenses
Catalogue of imported waste management	Aug 10, 2017	Dec 31, 2017	Unsorted wastepaper adjusted from ''Catalogue of solid waste used as raw materials under restricted import'' to ''Catalogue of banned import solid waste"
Provisions on environmental protection and management of imported wastepaper	Dec 14, 2017	Dec 14, 2017	Mill with production capacity less than 50,000 tons/yr prohibited from importing wastepaper
Environmental protection control standard for imported solid wastes as raw materials—Waste and scrap of paper or paperboard	Dec 29, 2017	Mar 1, 2018	Contamination rate cut from 1.5% to 0.5%

recover and process wastepaper increased because of stricter quality requirements. This makes the recycling enterprises in the international market subject to profit loss resulting from increases in processing costs and decreases in final product price. In short, the new policies weakened the relationship between the Chinese and international wastepaper markets and caused severe price fluctuations in both markets, threatening the stable development of China's paper industry and global recycling industry. With further enforcement, these policies will continue to create profound impacts on both Chinese and international wastepaper markets. Therefore, the analysis of how the integration relationship between the Chinese and international wastepaper markets is affected by the implementation of China's new wastepaper policies is of paramount importance.

Regional markets that are actively involved in transborder trades are always integrated with related markets, which is beneficial to the overall improvement and stabilization of the global market (Stoica et al. 2015, Kuuluvainen et al. 2018, Murali et al. 2019). Market integration refers to the comovement of price, and more generally to the smooth transmission of price signals and information across spatially separated markets (Goletti et al. 1995). The market price of goods serves as the medium of information flow. If the markets are integrated, resources and information will be freely shared and transmitted among the markets, and the market prices of goods will only differ by transaction costs (Jaunky and Lundmark 2015). Existing studies have argued that market integration carries advantages including increased price stabilization, more efficient resource allocation, higher resilient market liquidity, and reduced likelihood of asymmetric shocks (Goletti et al. 1995, Umutlu et al. 2010, Yu et al. 2010). Complete market integration ensures that a balance occurs among resource-deficit and resource-surplus regions and the price differences among the regions are minimized by close trade interactions (Baulch 1997, Murali et al. 2019). Contrary to this, if a weak degree of market integration presents, an incomplete price transmission will occur, resulting in localized scarcities and abundances and thereby causing price fluctuations in the regional markets (Ravallion 1986). Thus, the understanding of market integration is essential for making appropriate decisions. By giving a more detailed picture of the trade relationship among the related markets, knowledge about the degree of market integration will inform the decision makers on resource and goods flows and suitable responses to changing market conditions.

A measurement of market integration can be viewed as basic information needed to comprehend the functionality of the specific markets in the whole market scenario (Ravallion 1986). Since market integration is best understood by studying the relationship of market prices rather than trade flows, and market price is the best variable to reflect market development, existing studies have extensively used price series to investigate market integration (Jaunky and Lundmark 2015). Most studies examine market integration with cointegration test (Niquidet and Manley 2008, Ankamah-Yeboah and Bronnmann 2018), vector autoregression (VAR) model (Mafimisebi 2013), generalized autoregressive conditional heteroscedasticity (GARCH) model (Bekaert and Mehl 2019), and VAR-GARCH model (Caporale and Spagnolo 2012). These methods can inspect the existence of market integration but cannot reflect the status and dynamics of the degree of market integration over time, especially how it changes in response to policy interventions or other anomalies. Thus, the measurement of the degree of market integration has become another focus of related research that could assist government and enterprises in formulating and adjusting policies and strategies. Spillover effects can reflect the degree of market integration and are widely analyzed on the basis of versions of VAR models (Gębka and Serwa 2007, Carpio 2019) and GARCH models (Singh et al. 2010, Balli et al. 2019, Carpio 2019). Multivariate GARCH models and VAR models test the spillover effect through the significance of estimated parameters. Moreover, the variance decomposition of the VAR model and the GARCH model can be used to identify spillovers of shocks from or to other markets (Gębka and

Serwa 2007, Carpio 2019). However, these methods fail to detect the time-varying characteristics of spillover effects. The spillover index method developed by Diebold and Yilmaz (2009) is favored by recent studies because it can precisely quantify the extent of spillovers in a simple and reliable way (McMillan and Speight 2010, Shahzad et al. 2017). Most importantly, this methodology allows some extensions (Caloia et al. 2018, Wang and Guo 2018). Combined with rolling regression, it can be used to reflect the dynamics of spillover effects. Wang and Guo (2018) constructed a spillover index to explore the volatility spillover effects between carbon and energy markets and adopted the rolling regression analysis to detect the time-varying property of the spillover effects.

This study intends to investigate the impact of China's new wastepaper policies on the degree of integration between the Chinese and international wastepaper markets and analyze the dynamics of the relationship between the two markets over time.

Methodology and Data

Methodology

Spillover index.—We use the spillover index developed by Diebold and Yilmaz (2009) to investigate the integration between Chinese and international wastepaper markets. The index is built upon decomposition of forecast error variance associated with an N-variable VAR model. One of the most attractive advantages of this index is that it provides a simple quantitative measure of the extent of market interdependence by giving the fraction of forecast error variance in a system of markets explained by cross-market shocks. The spillover index ranges within [0, 1], and the higher the index value, the stronger the integration among the markets. Moreover, by incorporation with other methods, the index can be calculated on a time-varying basis, which enables further investigation into the dynamics of the degree of integration.

The method starts with a conventional VAR model. Consider a simple example of a covariance stationary first-order two-variable VAR as below:

$$x_t = \Phi x_{t-1} + \varepsilon_t \tag{1}$$

where $x_t = [x_{1,t}, x_{2,t}]'$ and Φ is a 2 by 2 coefficient matrix. ε_t is a vector that is assumed to be independently and identically distributed. If x_t is covariance stationary, then the VAR model can be written as a moving average process:

$$x_t = \Theta(L)\varepsilon_t \tag{2}$$

where $\Theta(L) = (I - \Phi L)^{-1}$. Then rewrite Equation 2 as below:

$$x_t = A(L)u_t \tag{3}$$

where $A(L) = \Theta(L)Q_t^{-1}$, $u_t = Q_t\varepsilon_t$, $E(u_t u_t') = I$, and Q_t^{-1} is the low-triangular Cholesky factor of the covariance matrix of ε_t.

Now a one-step-ahead forecast can be obtained by

$$x_{t+1,t} = \Phi x_t \tag{4}$$

The corresponding one-step-ahead error vector is calculated as

$$e_{t+1} = x_{t+1} - x_{t+1,t} = A_0 u_{t+1} = \begin{bmatrix} a_{0,11} & a_{0,12} \\ a_{0,21} & a_{0,22} \end{bmatrix} \begin{bmatrix} u_{1,t+1} \\ u_{2,t+1} \end{bmatrix} \tag{5}$$

Then we can get the error covariance matrix:

$$\begin{aligned} &E(e_{t+1}, t, e'_{t+1,t}) \\ &= A_0 A_0' \\ &= \begin{bmatrix} a_{0,11}^2 + a_{0,12}^2 & a_{0,11}a_{0,21} + a_{0,12}a_{0,22} \\ a_{0,21}a_{0,11} + a_{0,22} & a_{0,12}a_{0,21}^2 + a_{0,22}^2 \end{bmatrix} \end{aligned} \tag{6}$$

Thus, the variance of the one-step-ahead forecast error is given by

$$\begin{aligned} \sigma_{x1,t}^2 &= a_{0,11}^2 + a_{0,12}^2 \\ \sigma_{x2,t}^2 &= a_{0,21}^2 + a_{0,22}^2 \end{aligned} \tag{7}$$

and the total forecast error variance of the system is

$$\sigma_{x,t}^2 = a_{0,11}^2 + a_{0,12}^2 + a_{0,21}^2 + a_{0,22}^2 = \text{trace}(A_0 A_0') \tag{8}$$

Variance decompositions allow us to split the forecast error variance of each variable into parts attributable to its own shocks or shocks to other variables. For example, the total forecast variance of $x_{1,t}$, namely $\sigma_{x1,t}^2$, can be separated into two parts: $a_{0,11}^2$, which represents the forecast variance due to its own shocks, and $a_{0,12}^2$, which represents the forecast variance due to shocks to x_2. Diebold and Yilmaz (2009) defined the fraction of the one-step-ahead error variances in forecasting x_i due to shocks to x_i as own variance shares, for $i = 1, 2$; and the fraction of the one-step-ahead error variances in forecasting x_i due to shocks to x_j as cross-variance shares, or spillovers, for $i, j = 1, 2, i \neq j$. Thus, in terms of $\sigma_{x2,t}^2$, $a_{0,22}^2$ is the own variance shares and $a_{0,21}^2$ is the spillovers.

Hence, there are two possible spillovers in our two-variable VAR model, and the total spillovers (TS) of the system are

$$\text{TS} = a_{0,12}^2 + a_{0,21}^2 \tag{9}$$

The TS can be converted into an easily interpreted index by expressing it as a fraction of the total forecast error variance. Thus, the spillover index is given by

$$S = \frac{\text{TS}}{\sigma_{x,t}^2} = \frac{a_{0,12}^2 + a_{0,21}^2}{\text{trace}(A_0 A_0')} \times 100 \tag{10}$$

We can generalize the index to a pth-order N-variable VAR model, using H-step-ahead forecasts. Then the index could be represented as

$$S = \frac{\sum_{h=0}^{H-1} \sum_{j=1}^{N} \sum_{i=1}^{N} a_{h,ij(i \neq j)}^2}{\sum_{h=0}^{H-1} \text{trace}(A_h A_h')} \times 100 \tag{11}$$

Rolling regression.—The full-sample-based static spillover index alone is insufficient in revealing the dynamic evolution of spillover overtime. Thus, to investigate the dynamics of the degree of integration between the Chinese and international wastepaper markets, this study applied the rolling regression method to catch the time-varying characteristics of the spillover index. The main idea of this method is to use the subsamples in the overall sample to estimate, and the calculated time-varying estimates can be used to interpret findings (Zanin and Marra 2012).

E-Divisive with Medians.—To evaluate the impacts of the newly implemented policies on the integration relationship between the Chinese and international wastepaper markets, we adopted the previously developed E-Divisive with Medians (EDM) method by James et al. (2014) to detect structural breaks in the dynamic TS index. The EDM method is suitable for this study because unlike existing methods for break detection, it is robust against the presence of anomalies, where in this study the new policies emerge as external interventions to the Chinese and international wastepaper markets. EDM uses E-statistics to detect divergence in mean and variance. It uses robust statistical metrics of median and estimates the statistical significance of a break through a permutation test. Moreover, EDM is nonparametric, which is applicable to nonnormalized distributions.

Data

Table 1 lists the major new policies on wastepaper in China from 2013 to 2018. With the aim of mitigating the negative environmental impacts from wastepaper imports, the Chinese government has implemented a series of new restrictive regulations on wastepaper imports, including tighter customs inspections and more stringent quality requirements on the imported wastepaper. These regulations would significantly reduce the volume of imported wastepaper, since the recycling enterprises in the international market could hardly update their processing technology and capacity to meet the stricter quality requirements in the short run. On the other hand, the tax rebate policy implemented in 2015 to promote the utilization of recycled materials and reduce energy consumption and greenhouse gas emissions greatly encouraged the paper industry to use wastepaper for production, leading to increased demand for wastepaper. Since domestic wastepaper supply is limited, the demand for imported wastepaper increased. Thus the wastepaper policies introduced in recent years are contradictory in their impacts on wastepaper trade. The import restrictions led to a dramatic decrease in China's wastepaper imports, whereas the tax rebate policy stimulated wastepaper demand and indirectly enhanced wastepaper imports.

We used monthly price data of China's domestic and imported wastepaper from January 2006 to November 2019. The domestic wastepaper prices from 2006 to 2017 and from 2018 to 2019 were obtained from the Wind Database (2018) and SCI99.com (2020), respectively. Raw data were in the form of monthly price in Chinese yuan and then converted to US dollars (USD) at the monthly average exchange rate. The imported wastepaper prices from 2006 to 2017 and from 2018 to 2019 were collected from China's General Administration of Customs (DRCnet 2018) and DATE's Data (2020), respectively. Raw data were in the form of import value (USD) and quantity (ton) by product and month. The price rate of change of China's domestic and imported wastepaper was calculated as the first difference of the log prices. PDOS and PDOR denote China's domestic wastepaper price and its rate of change, respectively. PIM and PIMR represent China's imported wastepaper price and its rate of change, respectively.

Figure 2 shows that China's domestic and imported wastepaper prices are all positively skewed and generally fall within the same range, with China's domestic wastepaper price more concentrated. At the same time, before 2017 China's domestic and imported wastepaper prices and their rates of change present similar movement patterns. Both prices drop sharply in 2008, recover gradually, and reach a peak in 2011. Following a continuous decline, both prices tend to be stable, with import price presenting a slight downward trend. During the period from 2010 to 2014, both domestic and imported wastepaper prices vary within the range of USD$180/ton to USD$280/ton, with a relatively small price difference between the two markets. In 2015, the domestic wastepaper price is relatively stable, whereas the imported wastepaper price shows a decline. From 2017 both prices present more fluctuations, with stronger variations presented in domestic price and its rate of change. Meanwhile, the price difference between the two markets expands gradually. In sum, the overall movement patterns of the domestic and imported wastepaper prices are consistent, indicating that the Chinese domestic and international wastepaper markets have strong correlations.

Results

We first performed the augmented Dickey–Fuller (ADF) unit root test on the logarithm of domestic wastepaper price (LPDO) and the logarithm of import price (LPIM) to examine whether the Chinese domestic and imported wastepaper prices were stationary. Then, we examined the existence of market integration between the Chinese and international wastepaper markets on the basis of a two-variable VAR model and conducted the Granger causality test to determine which of the two markets was the price leader. Following, we built spillover index on the basis of the VAR model to analyze the spillover effects between the two markets and incorporated rolling regression to investigate the dynamics of the spillover effects in response to China's implementation of new wastepaper policies. Finally, we conducted EDM to detect breaks in the dynamic TS index and analyzed the effects of the new policies on the integration relationship between the two markets. In this study, the lagged order in the VAR model was selected on the basis of the Akaike information criterion (AIC).

Since there are three forms of ADF unit root test, including the test for a unit root without constant and trend, the test for a unit root with a constant but no trend, and the test for a unit root with a constant and a time trend, the data-generating process (DGP) identification was first conducted to determine the proper form of unit root test. The results of DGP identification suggested that both LPDO and LPIM contained a constant but present no trend (see Table S1 in Supplemental Material). Thus, the unit root test with a constant but no trend was used on LPDO and LPIM, and the unit root test without constant and trend was used on their first differences in the following analysis.

Moreover, the stationarity of time series is sensitive to structural breaks and seasonality. Thus, the minimum Lagrange multiplier (LM) unit root test with two structural breaks and the Hylleberg–Engle–Granger–Yoo (HEGY) seasonal unit root test were applied to detect structural breaks and seasonality in LPDO and LPIM. The null hypothesis of LM unit root test is that there is no unit root with breaks. The two-break LM unit root test was performed for LPDO and LPIM both at level and in first difference, and the two break-point dates were estimated. The results of the two-break LM unit root test rejected the null hypothesis in first difference, indicating the presence of structural breaks in China's domestic and imported wastepaper prices (see

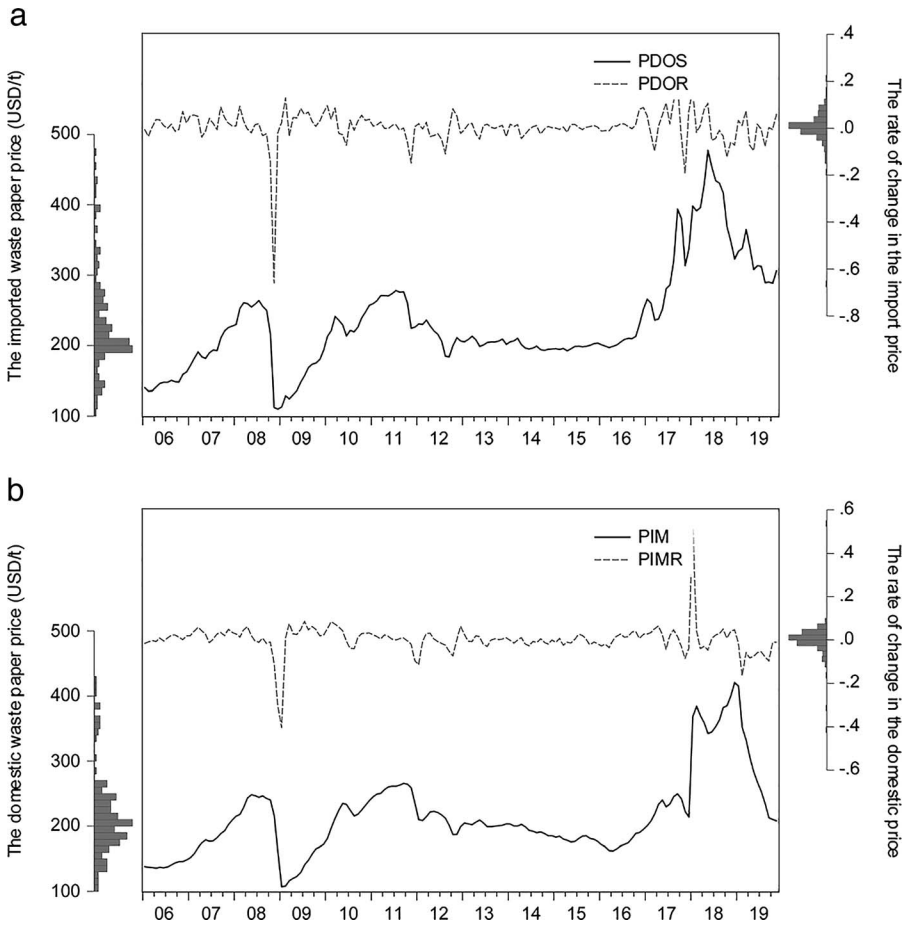

Figure 2.—China's domestic and imported wastepaper prices and their rates of change. (a) China's domestic wastepaper price (PDOS) and its rate of change (PDOR). (b) China's imported wastepaper price (PIM) and its rate of change (PIMR).

Table S2 in Supplemental Material). The break-point dates for domestic prices emerged in February 2007 and July 2008, respectively, whereas the break-point dates for import price lagged behind those for domestic price for about 1 year, which occurred in April 2008 and June 2009, respectively. The break-point dates coincided with the US subprime mortgage crisis and European debt crisis, which caused drastic fluctuations in the prices of major bulk products in the global market. Consistent with the global situation, a sharp drop and bounce occurred in the prices of wastepaper during the period (see Fig. 2).

The null hypothesis of the HEGY test is that a seasonal unit root exists. The results of the HEGY seasonal unit root test rejected the null hypothesis at most frequencies both at level and in first difference (see Table S3 in Supplemental Material). LPDO and LPIM were not significant only at frequency zero but were significant at other frequencies. The first difference of LPDO, namely PDOR, was significant at all frequencies, whereas the first difference of LPIM, namely PIMR, was not significant at 3-month and 6-month frequencies but significant at other frequencies. Therefore, the results implied an absence of seasonal unit roots in China's domestic and imported wastepaper prices.

According to the results of the two-break LM and HEGY unit root tests, both LPDO and LPIM contained structural breaks and seasonality. Thus, to obtain a more accurate examination of stationarity in the domestic and imported wastepaper price series, this study extracted the structural breaks and seasonal components from LPDO and LPIM through regression with dummy variables, and then applied the ADF unit root test on the processed series. The results of the ADF unit root test (see Table S4 in Supplemental Material) showed that both LPDO and LPIM with extraction of structural breaks and seasonality were nonstationary at level but stationary in first difference. Thus, the price rate of change of China's domestic and imported wastepaper, namely PDOR and PIMR, were used to build the two-variable VAR model. On the basis of AIC, two lags were chosen for all the independent variables in the VAR model (see Table S5 in Supplemental Material). The VAR model was estimated using the ordinary least squares method and the estimation results were reported in Table 2. Both PDOR and PIMR showed dependency on their past values, since the coefficients of their first-order lagged values were significant at the 1 percent level in the regressions, with themselves as dependent variables. For both PIMR and PDOR, the first-order lagged values had a significant positive effect on themselves and the second-order lagged values had a negative effect on themselves that was, however, insignificant. For the analysis of integration between the two markets, we focused on the coefficients of the cross-market lagged values. In the regression for PIMR, the coefficients of both first-order and second-order lagged values of PDOR were positive and significant at the

Table 2.—Results of vector autoregression model.[a]

Variable	PIMR	PDOR
PIMR (1)	0.253***[b] (0.078)[c]	−0.111 (0.095)
PIMR (2)	−0.110 (0.072)	0.105 (0.087)
PDOR (1)	0.304*** (0.066)	0.332*** (0.080)
PDOR (2)	0.203*** (0.071)	−0.117 (0.086)
Constant	0.000 (0.005)	0.004 (0.006)
Adj. R^2	0.321	0.101

[a] PIMR = rate of change of imported wastepaper price; PDOR = rate of change of domestic wastepaper price; (1) = first order; (2) = second order.
[b] *** = significant at the 1 percent level.
[c] Numbers in parentheses are standard errors.

1 percent level, indicating that the lagged values of PDOR had a significant positive effect on PIMR. In the regression for PDOR, none of the coefficients of first-order and second-order lagged values of PIMR was significant, suggesting that the lagged values of PIMR had no obvious effect on PDOR. Roots of characteristic polynomial were calculated to examine the stability of the VAR model (see Table S6 in Supplemental Material). Because no root lay outside the unit circle, the VAR model satisfied the stability condition. Given the VAR model, the Granger causality test was performed to determine the causality relationship between China's domestic and imported wastepaper prices (see Table S7 in Supplemental Material).The null hypothesis that PDOR does not Granger cause PIMR was rejected at the 1 percent level (χ^2/36.69; *P* value/0.00), indicating that PDOR was the Granger cause of PIMR, whereas the null hypothesis that PIMR does not Granger cause PDOR was not rejected (χ^2/2.08; *P* value/0.35), indicating that PIMR was not the Granger cause of PDOR.

We then calculated the static TS index on the basis of Equation 10 for the entire sample. We performed some variations on the forecast horizon in our analysis to check the robustness of the index. Thus, the spillover index was calculated with a forecast horizon of 3 months, 6 months, and 9 months. Table 3 provides the detailed calculation of spillover indices. The *ij*th entry in each selected forecast horizon in Table 3 represents the estimated contribution to the forecast error variance of market *i* originating from market *j*. The sum of the first two values in the row of contributions to others or that of the first two values in the column of contributions from others gives the numerator of the spillover index, which refers to the TS. The sum of the first two values in the row of contributions including own gives the denominator of the spillover index, which refers to the total forecast error variance of the system. The italicized values are the calculated spillover indices. According to Table 3, innovations to PIMR are responsible for 4.20 percent of the forecast error variance of PDOR at the 3-month forecast horizon. Innovations to PDOR are responsible for 27.50 percent of the forecast error variance of PIMR at the 3-month forecast horizon. The TS index is 15.90 percent in the 3-month-ahead forecast. In the cases of 6-month-ahead and 9 month-ahead forecast error variance decomposition, innovations to PIMR explain 4.60 percent of the forecast error variance of PDOR, whereas innovations to PDOR explain 30.40 percent of the forecast error variance of PIMR, and the TS index is 17.50 percent in both cases. On the basis of the above results, the spillovers from PDOR to PIMR are much higher than those from PIMR to PDOR. This result corroborated our findings of China's leading position in price formation and transmission. In addition, the variation in forecast horizon leads to significant difference in TS indices, with a spillover index of 15.90 percent for 3-month-ahead forecast and a spillover index of 17.50 percent for both 6-month-ahead and 9-month-ahead forecasts. When the forecast horizon is set longer than 9 months, the TS index fixes at 17.50 percent. Therefore, the TS index calculated at the 9-month forecast horizon is more reliable.

The static TS index calculated with full sample showed the spillovers between the two markets from an overall and average perspective. However, a series of inconsistent policies was implemented during the period studied and brought many changes to the wastepaper markets, so the single static spillover index seems unlikely to apply over the entire sample. To capture the dynamic evolution of spillover index over time, we estimated the TS index with an 18-month rolling window. We exhibited three dynamic TS indices on the basis of forecast horizons of 3 months, 6 months, and 9 months, respectively, in Figure 3 to test the robustness of the index. As Figure 3 shows, the difference between the dynamic TS indices reduced with an increasing forecast horizon, indicating stronger robustness with a longer forecast horizon. Thus, we focused on the dynamic TS index on the basis of the 9-month forecast horizon for

Table 3.—Spillover index on the basis of the two-variable vector autoregression model.[a]

Forecast horizon	To	From PIMR	From PDOR	Contribution from others
3-month	PIMR	72.50	27.50	27.50
	PDOR	4.20	95.80	4.20
	Contribution to others	4.20	27.50	31.80
	Contribution including own	76.7	123.3	*15.90%*[b]
6-month	PIMR	69.6	30.4	30.4
	PDOR	4.6	95.4	4.6
	Contribution to others	4.6	30.4	35
	Contribution including own	74.2	125.8	*17.50%*
9-month	PIMR	69.6	30.4	30.4
	PDOR	4.6	95.4	4.6
	Contribution to others	4.6	30.4	35.1
	Contribution including own	74.2	125.8	*17.50%*

[a] PIMR = rate of change of imported wastepaper price; PDOR = rate of change of domestic wastepaper price.
[b] Italicized values are the calculated spillover indices.

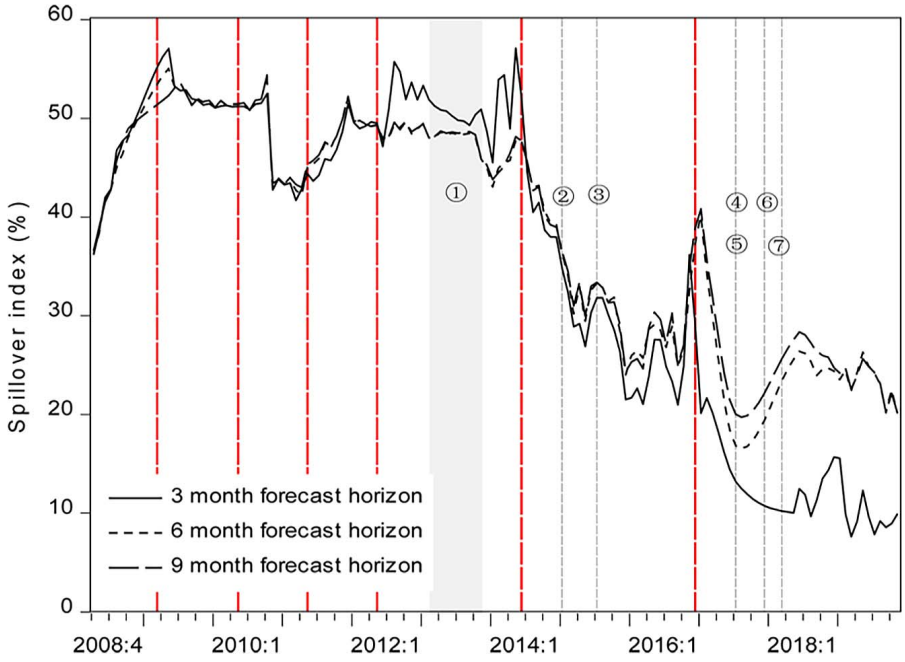

Figure 3.—Dynamic total spillover index and structural breaks on the basis of E-Divisive with Medians (EDM) with a 9-month forecast horizon. The numbers in the circles denote the newly implemented policies listed in Table 1; the red lines represent the structural breaks identified by EDM with 9-month forecast horizon.

the subsequent analysis. Figure 3 shows that the dynamic TS index varies widely between 20 and 55 percent, fluctuating around 45 percent by 2013 and presenting a downward trend thereafter. Since 2013 the dynamic TS index presents several significant fluctuations corresponding to the implementation of new policies on wastepaper. At first, there emerges a slight decline in early 2013, which is probably due to Operation Green Fence. The TS index then recovers quickly and reaches the highest level of approximately 50 percent at the beginning of 2014. A continuous decrease follows because of tightened regulations on wastepaper imports until the implementation of *Comprehensive Utilization of Resources and Labor VAT Preferential Directory* in mid-2015. Attributed to the promulgation of the tax rebate policy, the TS index increases sharply in mid-2015. After that, the index continues to subside and drops to the lowest level of 19.63 percent in mid-2017, with a series of import restriction policies announced during the period. Then the spillover index increases to a periodic peak of 28.24 percent in mid-2018, which is much lower than the average level before the implementation of the restrictive wastepaper import policies and remains on an overall downward trend since then.

To identify the effects of the newly implemented policies on the integration relationship between Chinese and international wastepaper markets, we conducted EDM on the calculated dynamic TS index both in mean and standard deviation, where the mean reflected the degree of integration and the standard deviation depicted the variations in the integration relationship. EDM detected six structural breaks, which divided the whole period into seven subperiods and the seven new policies into three groups. The three groups of policies are located in the latter three subperiods, with policy 1 in subperiod 5, policies 2 and 3 in subperiod 6, and policies 4, 5, 6, and 7 in subperiod 7 (see Fig. 3 and Table 4). The null hypothesis of equal means was rejected at the 1 percent level (χ^2/121.75; *P* value/0.00), and the null hypothesis of equal variance was also rejected at the 1 percent level (χ^2/79.19; *P* value/0.00), suggesting that significant differences existed in the degree of integration between the two markets among the subperiods. Furthermore, the results showed that the means and standard deviations of subperiods 6 and 7 exhibited strong divergence from those of previous subperiods (see Table 4). For the first five subperiods covering April 2008 to May 2014, the means generally fell within the small range of 45 to 52 percent, demonstrating that the degree of integration between the two markets was relatively stable during the period. Along with the implementation of a series of stricter policies since 2015, the means of the latter subperiods dropped dramatically. The means of subperiods 6 and 7 were 32.78 and 25.29 percent, respectively, much lower than those of the previous subperiods, indicating that the degree of integration was greatly weakened with the implementation of the new policies since 2015. In terms of the standard deviations, the largest three were from subperiods 6, 1, and 7, which coincided with the implementation of policies 2 and 3, the 2008 global financial crisis, and the implementation of

Table 4.—Results of E-Divisive with Medians on dynamic spillover index on the basis of a 9-month forecast horizon.

No.	Period	Observed	Mean (%)	SD
1	Apr 2008–Feb 2009	11	45.61	5.10
2	Mar 2009–Apr 2010	14	51.82	0.73
3	May 2010–Apr 2011	12	47.57	4.59
4	May 2011–Apr 2012	12	48.24	2.02
5	May 2012–May 2014	25	47.71	1.64
6	Jun 2014–Nov 2016	30	32.78	6.38
7	Dec 2016–Nov 2019	36	25.29	4.94
All	Apr 2008–Nov 2019	140	39.03	11.11

policies 4, 5, 6, and 7 (see Fig. 3). Thus, the implementation of the new restrictive policies had significant impacts on the integration relationship between Chinese and international wastepaper markets. These policies largely reduced the degree of integration between the two markets in general and led to more fluctuations and uncertainties in the integration relationship.

Discussion

The results of the VAR model and Granger causality test showed that the Chinese and international wastepaper markets were integrated, with the Chinese market as the price leader. Since market integration enables smooth price transmission and free resource circulation across the integrated markets, resource imbalance and price differences among the markets will be cut off with trade. Thus, the integration relationship between the Chinese and international wastepaper markets contributes greatly to the relief of the wastepaper supply shortage in China's paper industry and the stability of both markets. The finding of the Chinese market as the price leader is not surprising, as China is the world's largest importer of wastepaper and will therefore exert significant influence on the international wastepaper market. Because the Chinese and international wastepaper markets are integrated, with China as the price leader, changes in the Chinese market will inevitably affect the international market. Hence, China's new wastepaper policies will lead to changes and fluctuations in both markets.

The static and dynamic spillover indices developed on the basis of the VAR model provide more insight into the degree of integration between the two markets. A high spillover index implies a high degree of integration, and vice versa. The single static spillover index was first calculated with the full sample, which reflected the average spillover effects between the two markets during the period studied. The calculated TS index of 17.50 percent confirmed that the Chinese and international wastepaper markets were integrated, but at a relatively low level on average. The degree of integration reflects the closeness of dependence and interactions among the related markets, which will thus be affected by the diversity and quantity of available substitutions. Although wastepaper is the dominant fiber material for China's paper industry, it has a lot of substitutes, such as virgin wood fibers. The increased wastepaper price may trigger the substitution effect of wood pulp for recycled pulp, resulting in decreased demand for wastepaper and increased demand for wood pulp. Thus, the substitution effect between wastepaper and virgin wood fibers makes the integration relationship between the Chinese and international wastepaper markets remain at a relatively low level.

However, the static TS index only reflects the average behavior and fails to describe the dynamic of the spillover effect. The newly implemented policies brought about fluctuations in both Chinese and international wastepaper markets and in the relationship between them. To investigate how the integration relationship between the two markets changes in response to the new policies, rolling regression was applied to capture the time-varying characteristics of the spillover effects between the two markets. The dynamic TS index in Figure 3 presents an overall declining trend with large fluctuations due to the implementation of new policies and regulations. Policies and regulations could promote or mitigate the spillover effects between markets on the basis of different influence mechanisms. The value-added tax (VAT) rebate policy in 2015, for example, encouraged the papermaking companies to use wastepaper for paper production, resulting in increased demand for wastepaper. Because China is highly dependent on the international wastepaper market, the increased wastepaper demand stimulated wastepaper imports and thereby enhanced the interactions between the Chinese and international wastepaper markets. The wastepaper imports of China in 2015 were 29.28 million tons, which was 1.77 million tons more than in 2014, with an increase of 6 percent (FAO 2019). The spillover index increased upon the promulgation of the VAT rebate policy accordingly. On the other hand, the wastepaper import restrictions created trade barriers, thus negatively affecting the interactions between the two markets. Operation Green Fence in 2013 reduced the wastepaper imports during the operation period and the spillover index decreased slightly accordingly. Because the operation lasted only 10 months, the index recovered quickly to the previous level in 2014. The subsequent policies since 2015, including the ban on unsorted wastepaper and the stricter standard requirements for the quality of imported wastepaper, led to dramatic plunges in the volume of wastepaper imported by China. Thus, the newly implemented policies were inconsistent in their impacts on the integration relationship between the Chinese and international wastepaper markets, which imposed more fluctuations and uncertainties on both markets. Furthermore, the overall decreasing TS index indicated that the negative effects from the restrictive policies were more significant and the integration between the two markets was weakened as a result.

Finally, the results of EDM detected six structural breaks in the dynamic spillover index and provided a way to evaluate the impacts of the new policies on the degree of integration between the two markets. In line with above analysis, the results of EDM detected a slight decrease in the mean of the dynamic TS index for the period covering 2013 and significant decreases in the means of the dynamic TS index for 2015 and following years. According to the results listed in Table 4, the mean of the dynamic TS index from May 2012 to May 2014 was only 1.10 percent lower than that of its preceding period, suggesting that Operation Green Fence implemented in 2013 caused a temporary and limited impact on the integration relationship between the two markets. The mean of the dynamic TS index from June 2014 to November 2016 decreased sharply by 31.29 percent from its preceding period, indicating that the negative effect from the restrictive import policy overrode the promotion effect from the tax rebate policy during the period and significantly reduced the integration relationship between the two markets. The mean of the dynamic spillover index from December 2016 to November 2019 was 22.85 percent lower than that of its preceding period, demonstrating that the integration relationship between the two markets was further impeded by the new restrictive policies during the period. It can be inferred from the above analysis that the restrictive wastepaper policies of the ban on unsorted wastepaper and stricter quality requirements implemented since 2015 have imposed significant negative impacts on the integration relationship between the two markets.

The break of the integration relationship between the two markets because of the implementation of the new restrictive wastepaper import policies has created a multitude of fluctuations and uncertainties in the Chinese and international wastepaper markets and will continue to affect the stable development of China's paper industry and international recycling industry in the short run. Regarding the Chinese market, with the tightening of wastepaper import policies, China's wastepaper imports dropped from 29.28 million tons in 2015 to 17.03 million tons in 2018, a decrease of 58.16 percent (FAO 2019). Since China is highly dependent on imported wastepaper, the sharp decrease in wastepaper imports resulted in supply shortage and increased price in China's wastepaper market, with domestic price increased by more than 50 percent from 2015 to 2019 (Wind Database 2018, SCI99.com 2020). Although the increased price will promote the domestic wastepaper recycling capacity, the improvement is far from enough to compensate for the sharp decline in wastepaper imports. The huge fiber material demand of China's paper industry triggered the substitution effect of wood pulp for wastepaper, which inevitably enhanced the demand for forest resources. The consumption of wood pulp increased from 27.18 million tons in 2015 to 28.92 million tons in 2018 and the proportion of wood pulp in the total pulp consumption increased from 25.25 percent in 2015 to 29.47 percent in 2018 (FAO 2019). With decreases in recycled pulp consumption and increases in wood pulp consumption, the changes in China's pulp structure will bring about challenges to the current papermaking technology and production capacity of China's papermaking enterprises due to limited time and ability to make proper adjustments in the short term. Furthermore, the wastepaper supply shortage in the Chinese market has pushed the prices of both wastepaper and wood pulp to increase. The margins of China's papermaking enterprises shrank as a result of the soaring costs of materials, which may lead to either price increases in the final products or mill closures.

The international wastepaper market is facing great risks and challenges as well. The newly implemented restrictive policies weakened the integration relationship between the Chinese and international wastepaper markets and led to supply shortage in the Chinese wastepaper market and supply surplus in the international wastepaper market. Thus, the price difference between the two markets expanded, and the price in the international market dropped sharply. Meanwhile, to meet the more stringent quality requirements, the cost of recovering and processing wastepaper increased, which left the recycling enterprises in a dilemma of increased processing cost and decreased final product price. Moreover, the sharp decline in demand and the slower processing rates due to the higher quality requirements led to stockpiling in the recycling enterprises. Since they are unable to adjust their processing capacity in the short term, some of the wastepaper will be disposed of by incineration or in landfills, which may have a negative effect on the environment.

In summary, the newly implemented restrictive wastepaper import policies have significantly reduced the integration between the Chinese and international wastepaper markets, broken the supply–demand balance in both markets, and led to more price fluctuations and larger price differences between the markets, which is unfavorable to the stability of both markets and the stable development of China's paper industry.

Conclusion

The purpose of this study was to investigate the impact of China's newly implemented wastepaper polices on the degree of integration between the Chinese and international wastepaper markets. We built a two-variable VAR model to explore the integration relationship between the two markets and constructed both the static and dynamic TS index to analyze the degree of integration in average and in time-varying perspectives. Finally, we performed EDM on the dynamic spillover index to evaluate more precisely the impacts of the new policies on the degree of integration between the two markets. The results of the empirical analysis revealed that the Chinese and international wastepaper markets were integrated but at a relatively low level on average. The dynamic TS index varied widely during the studied period and presented an overall decline trend since the implementation of the restrictive policies, indicating that these policies have weakened the integration relationship between the two markets. The results of EDM detected structural breaks in the dynamic spillover index due to the new policies, further confirming and describing the negative impacts of the new policies on the integration relationship between the two markets. Since strong mutual dependence exists between the Chinese and international wastepaper markets, the interventions to the integration relationship have broken the balance between the two markets and led to serious supply shortage and supply surplus in the Chinese and international markets, respectively, resulting in dramatic fluctuations in both markets and an expanding price difference between the two markets. The soaring price of wastepaper in the Chinese market and the plunging price of wastepaper in the international market exposed Chinese papermaking enterprises and international wastepaper recycling enterprises to increasing cost, shrinking margins, and more market risks and uncertainties, threatening the stable development of both the Chinese paper industry and the global recycling industry.

The results have important implications for Chinese papermaking enterprises and global wastepaper recycling enterprises. From the results, the market response to the new polices can be extracted to help the related enterprises predict the trend, assisting the decision makers in making timely and proper adjustments to their trade and production strategies. Furthermore, the results could help the government understand and evaluate the impacts of the new policies. Since China is highly dependent on imported wastepaper to meet the fast-growing demand for paper products, the increased price of wastepaper and the limited promotion potentials in China's wastepaper recycling capacity would lead to fiber shortage in China's paper industry and may trigger a substitution effect of wood pulp for recycled pulp. Therefore, the Chinese government should appropriately relax the import restrictions on wastepaper to ensure the wastepaper supply for China's paper industry, which is beneficial to the sustainable development of forest resources and the stable development of China's paper industry.

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