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Estimation of Recycled Paper Demand Function in Iran: Cointegration Approach

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Abstract:

This study aims to estimate the demand function for recycled paper in the Iranian economy during the seasonal period of 2000 to 2021. The Johansen-Juselius cointegration method was used to identify the factors influencing demand in both the long and short term. Quarterly data were generated from annual figures using the Denton method, and the model was specified in a linear logarithmic form.

The model's variables include per capita consumption of recycled paper, its price, the price of virgin paper, the percentage of internet users, and Gross Domestic Product (GDP). A dummy variable was also included to account for the removal of the import tariff in 2018. The results indicate that recycled paper is a necessary and inelastic good. In the long term, it becomes an inferior good, meaning that as income and welfare increase, consumers and producers shift towards higher-quality virgin paper.

In the short term, demand is influenced by changes in GDP, the price of recycled paper, and the internet. The price elasticity of demand is very low (0.012%), suggesting that price changes have a negligible impact on the quantity demanded. The error correction model (ECM) coefficient of -0.51 indicates that half of the short-term disequilibrium is corrected in each period.

These findings emphasize the importance of government policies in encouraging recycling and managing the market. Given Iran's limited forest resources, focusing on this sector can contribute to economic and environmental sustainability. Future research could explore the impact of tax and subsidy policies on the paper recycling industry.

1.Introduction:

The rapid growth of the world's population, coupled with increasing industrialization and consumerism, has led to a significant increase in the use of resources (Jing et al., 2023). The surge in global population is one of the key

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drivers of the increased in waste production and preserving human well-being within the environment remains paramount (Katpatal et al., 2024).

Paper is an integral part of our daily lives (Ma et al., 2017). Currently, in the world, paper remains the most reliable form for information encryption, security, authenticity, long-term archival storage, permanence (Zhao et al., 2022), as currency to activate the economic sector (Ren et al., 2020), and so on. The pulp and paper industry often produces products with a short lifespan compared to the solid wood products sector (Shorgen et al., 2019). Considering the limited forest resources, one of the solutions that can help preserve these resources is the recycling of waste paper (Van Ewijk et al., 2018).

On the other hand, in recent decades, the internet, along with information and communication technologies such as personal computers and mobile phones, has become an electronic substitute for newspapers and printed materials (Greg et al., 2016). Many studies have been conducted in this field, including studies by Filistruchi et al., 2005; Latta et al., 2015; Johnston, 2016. Min Dai et al. 2023 investigated the demand for paper production, waste paper recycling, and virgin fiber supply in 2023 and 2050 under different scenarios. They concluded that China's paper demand will increase to 186 million tons in the next 30 years, which will lead to a significant increase in demand for fibers. Chas-Amil and Buongiorno in a 2000 study estimated the demand equations for paper and board in 15 European countries. The results confirmed the hypothesis of equal income and price elasticity in all EU countries at a significance level of 1%. They also stated that from 1969 to 1995, the growth in demand was mainly due to the growth in national production and the increase in wood prices had a negative effect on the demand for paper and board.

With the rapid development of the e-commerce industry, online shopping, the volume of express delivery of purchases, and the packaging of shipped goods (which is mostly made from recycled paper) have increased (Kong, 2021). This rapid growth has also increased the number of players in the market and made the competition more intense and dynamic, causing frequent disruptions. In such an environment, planning for the purchase and forecasting the price of recycled paper is a big challenge. The paper industry, with the advent of modern and digital commerce, strengthening environmental awareness, global economic growth, and population development, is shifting from cellulose to recycled paper in the production process (Markovic and Mihic, 2022). In Iran, given the level of production and consumption of various paper products and the fact that population and income growth affect demand, it is very important for policymakers in the economic sector to be aware of the demand structure of individuals in society in order to plan for the production of various goods and services. and examining the consumer behavior pattern in response to price and income changes.

In this regard, in order to develop the production industry of this product, it is necessary to identify the factors affecting the demand for recycled paper and calculate the type of relationship between the dependent and explanatory variables and the amount of impact accurately in the form of econometric models. So that based on it, the future consumption of recycled paper can be accurately predicted. Therefore, this research investigates the demand for recycled paper in Iran.

2. Literature Review

In recent decades, global paper consumption has significantly increased due to population growth and economic development, raising concerns about natural resources, particularly forests. Jing et al. (2023) emphasized the importance of raw material management and effective waste paper management in the pulp and paper industry, stating that sustainable strategies are vital for the industry's progress. Similarly, Katpatal et al. (2024) highlighted the importance of preserving natural resources and focusing on environmental sustainability in the face of a growing global population. Given these challenges, paper recycling has emerged as an effective solution to reduce pressure on natural resources and supply raw materials to the paper industry (Shorgen et al., 2019). Furthermore, Kumar Pati et al. (2006) demonstrated the economic benefits of recycling over using wood as a raw material, emphasizing its efficiency in paper production.

Another important trend in recent studies is the role of information and communication technology (ICT), particularly the internet, in paper demand. Ren et al. (2020) examined the properties of paper and banknotes using terahertz spectroscopy but did not comprehensively analyze the direct impact of the internet on paper demand. Meanwhile, some studies have shown that the spread of the internet and digitalization of processes have gradually reduced paper consumption for purposes like newspapers and administrative documents. Nevertheless, phenomena such as e-commerce and the increase in online shopping have boosted the demand for packaging materials, including cardboard and recycled paper, indicating a dual impact on the paper market.

In terms of methodology, many economic studies have used Vector Autoregression (VAR) models to analyze the relationships between macroeconomic variables. For instance, Pahlavani, Wilson, and Worthington (2005) used an Autoregressive Distributed Lag (ARDL) model to investigate the relationship between trade and GDP in Iran, demonstrating the applicability of such methods in economic analyses related to Iran. The research by Sembiring et al. (2021) also highlighted the importance of supply chain models in the pulp and paper industry, which can aid in a more comprehensive analysis of the factors influencing production and consumption.

Based on the existing literature, there is a lack of a comprehensive study that simultaneously examines the impact of macroeconomic factors (such as GDP and prices) and new technologies (such as the internet) on the demand for recycled paper in the Iranian economy. This research aims to fill this gap using the Johansen joselius cointegration method and, by providing accurate results, help policymakers and industry stakeholders adopt better strategies for sustainable development.

3. Materials and Methods

Based on the conducted studies, the demand for recycled paper is a function of recycled paper price, GDP, substitute good price, and internet (Greg s. Latta et al., 2016 and FAO., 2007). In this study, due to the elimination of recycled paper import tariff since 2018, a dummy variable (Dum) was added to the model. The issue of eliminating the import tariff on recycled paper was raised by the Ministry of Industry, Mine and Trade in the meeting on February 29, 2017 in the Article One Commission and the members of the commission agreed, based on which the elimination of one percent import tariff was applied in the Export and Import Regulations of 2018. The linear logarithmic model form directly measures the elasticities and sensitivity of the variables and reduces the heteroscedasticity variance in the model (Ghatak and Siddiki, 2001; Pahlavani et al, 2005). Therefore, the model is specified in the linear logarithmic form as follows (Equation 1).

$$y_t = A_1 y_{t-1} + \cdots + A_P y_{t-p} + \varepsilon_t$$

A 5×1 vector consists of (LnCRt, LnCPt, LnGDPt, LnPrt, LnInternet t).

In the above model, (Ln) at the beginning of the variables indicates the natural logarithm of the variables.

- CRt denotes per capita consumption of recycled paper in tons in year t,
- Prt represents the price index of recycled paper in year t,
- Cpt is the price of virgin paper as a related good to recycled paper in tons in year t,
- Internet Users Percentage Share in Year t
- GDPt is the gross domestic product in year t,
- and ε_t is the error term.

In this study, the required statistics, information, and data were collected from the Central Bank of Iran, the Statistical Center of Iran, the Food and Agriculture Organization of the United Nations (FAO), and the International Telecommunication Union. The period of study is 2000-2021, which has been converted to quarterly data using the Denton method. In estimating time series regression models, the stationarity of the series should first be checked to select the appropriate model. Then, the Johansen system cointegration approach (1988) is used to investigate the factors affecting the demand for recycled paper. Therefore, to estimate the model, first, unit root tests were performed on all

variables using the HEGY test. Also, Eviews 13 software package was used for estimation.

4. Results and discussion

4.1. Unit-root tests

The first step in estimating time series models is to investigate the stationarity of the variables used. Since the data used in this study are seasonal data, it is also necessary to test for the presence or absence of seasonal unit roots. For this purpose, the HEGY unit root test was used, which has three independent hypotheses. The first two hypotheses are based on the t-statistic and the third hypothesis is based on the F-statistic. If the test result confirms the presence of a seasonal unit root, then seasonal differencing is also necessary in addition to the usual differencing to remove non-stationarity.

Table (1): Results of HEGY's Non-Seasonal and Seasonal Unit Root Tests

Computational Statistics				Variable name
$F\pi_{3,4}$	$t\pi_2$	$t\pi_1$		
46.83	-6.97	-2.33	Including the intercept, trend, and dummy variable in the equation	lncp
48.80	-6.97	-2.01	Including the intercept and dummy variable in the equation	
49.04	-7.13	-2.37	With the width of the origin and trend	
48.97	-7.12	-2.05	With the width of the origin	
29.89	-5.7	-4.2	Including the intercept, trend, and dummy variable in the equation	lncr
30.4	-5.7	-2.6	Including the intercept and dummy variable in the equation	
30.36	-5.75	-2.44	With the width of the origin and trend	
30.86	-5.8	-2.64	With the width of the origin	
21.65	-4.69	-3.04	Including the intercept, trend, and dummy variable in the equation	lninternet
20.71	-4.58	-1.25	Including the intercept and dummy variable in the equation	
22.77	-4.80	-3.12	With the width of the origin and trend	
21.69	-4.68	-1.29	With the width of the origin	
51.97	-7.51	-3.8	Including the intercept, trend, and dummy variable in the equation	lnpr
49.27	-7.19	-2.47	Including the intercept and dummy variable in the equation	
54.24	-7.67	-3.89	With the width of the origin and trend	
51.41	-7.35	-2.53	With the width of the origin	
32.39	-6.05	-2.25	Including the intercept, trend, and dummy variable in the equation	lngdp
0.92	-1.08	-0.36	Including the intercept and dummy variable in the equation	
33.36	-6.18	-2.3	With the width of the origin and trend	
0.97	-1.13	-0.41	With the width of the origin	

The statistics of , $t\pi_1$, $t\pi_2$and $F\pi_{3\cap}\pi_4$ indicate the presence of a non-seasonal unit root (presence of a unit root at frequency zero), a seasonal unit root at the six-month frequency, and a seasonal unit root at annual frequencies, respectively. The results of the HEGY non-seasonal and seasonal unit root tests for the variables are presented in Table (1).

Based on the calculated values of the ADF statistic $t\pi_1$and its comparison with the critical values, the hypothesis of the existence of a non-seasonal unit root for all variables is not rejected. Therefore, all the variables under study have a non-seasonal unit root. While the calculated values of the $t\pi_2$and $F\pi_{3\cap}\pi_4$statistics for all variables showed that the hypothesis of the existence of a seasonal unit root at the six-month and annual frequencies is rejected, and all variables are free of seasonal unit roots. Therefore, there is no need for seasonal differencing.

4.2. Cointegration analysis

Johansen's (1988) cointegration analysis requires the determination of the optimal lag length P in the VAR model. Therefore, the Akaike Information Criterion (AIC), the Schwarz Bayesian Criterion (SC), the Hannan-Quinn Criterion (HQ), the Final Prediction Error (FPE) criterion, and the modified likelihood ratio tests (LR) are used.

Table (2) VECM test statistics and selection criteria in the order of the system

LR	FPE	AIC	SC	HQ	Criterion / Degree or length of interruption
NA	2.03e-06	1.084267	1.418788	1.216257	0
1018.417	1.04e-13	-15.70541	-14.53458	-15.24344	1
135.3605	1.78e-14	-17.49015	-15.48302*	-16.69821*	2
14.15844	2.98e-14	-17.01589	-14.17246	-15.89397	3
21.88069	4.18e-14	-16.75551	-13.07578	-15.30362	4
62.92739	1.96e-14	-17.64226	-13.12623	-15.86040	5
48.67410*	1.18e-14*	-18.34800	-12.99567	-16.23616	6
17.73762	1.83e-14	-18.21226	-12.02362	-15.77044	7
23.02398	2.29e-14	-18.44407*	-11.41913	-15.67228	8

*Indicates the optimal order of Lag

The above statistics for lag lengths P = 1, ..., 8 are presented in Table (2). As can be seen, the SC and LR criteria determine the lag length as P = 2, the FPE criterion determines the lag length as P = 6, and the AIC criterion determines the lag length as P = 8. Therefore, considering the seasonality of the data and the sample size considerations in the cointegration test and the estimation of the equilibrium relationships, the lag length P = 2 is selected.

Table (3) Cointegration tests

Maximum eigenvalue test				Trace test		
Null hypothesis	**The opposite hypothesis**	**Test statistics**	**Critical value 95%**	**The opposite hypothesis**	**Test statistics**	**Critical %95 value**
$r=0$	$r=1$	54.46*	34.80	$r\geq 1$	99.54*	76.97
$r\leq 1$	$r=2$	22.89	28.58	$r\geq 2$	45.08	54.07
$r\leq 2$	$r=3$	12.95	22.29	$r\geq 3$	22.18	35.19
$r\leq 3$	$r=4$	7.52	15.89	$r\geq 4$	9.23	20.26
$r\leq 4$	r=5	1.70	9.16	$r\geq 5$	1.70	9.16

Notes: (i) r stands for the number of cointegrating vectors.
(ii)/denotes rejection of null hypothesis of no cointegration at 5% significance level

Table (3) shows the results of the cointegration tests for a lag length of P=2. The trace test shows a long-run equilibrium relationship, and the maximum eigenvalue test also shows a long-run equilibrium relationship at the 5% significance level.

Table (4) Estimates of long-run cointegrating vectors (normalized).

LnCR	LnGDP	LnCP	LnPr	LnInternet	C
1	-0.469036 (0.04792)	-0.214214 (0.00950)	-0.012120 (0.00559)	0.055462 (0.00897)	-4.201473 (0.73349)

Note: Figures in parentheses indicate standard errors.

Table (4) shows the long-run equilibrium relationship. The sensitivity of recycled paper to GDP is 0.46%, which means that a 1% increase in GDP will increase the demand for recycled paper by 0.46%. Since this coefficient is positive and less than one recycled paper is an inferior commodity.
The price elasticity of recycled paper is 0.012%, which means that it is inelastic. A 1% increase in the price of printing and writing paper will increase the demand for recycled paper by 0.21%, and printing and writing paper is a substitute for recycled paper.
The 0.05% elasticity of the Internet shows that a 1% increase in Internet use will decrease the demand for recycled paper by 0.05%.

Table (5) Adjustment Coefficients

	LnCR	LOGGDP	LOGCP	LOGPR	LOGINTERNET
ECM	-0.24 (0.16)	0.78 (0.23)	-0.26 (0.36)	-0.46 (1.15)	-0.07 (0.04)

The numbers in parentheses are the standard deviations

Table (5) shows the estimated adjustment factors or Loading factors. These coefficients measure the speed of adjustment of variables to imbalances in the

system or error correction terms. In the event of an imbalance, i.e., a deviation from long-term equilibrium relationships, some variables must bear the burden of adjustment to achieve these equilibrium relationships. Otherwise, there is no guarantee that the variables in the system will converge.

In the model under discussion, the recycled paper demand variable is adjusted by a coefficient of 0.78 for the GDP imbalance, and its value also indicates a high speed of instability relative to the said imbalance. In fact, more than half of the imbalance in recycled paper consumption in the next period is corrected by changes in GDP. The coefficient is significant. The variables of printing and writing paper price, Recycled paper price and recycled paper demand are adjusted by a factor of 0.26, 0.46, and 0.24 due to imbalance. The internet variable also has the lowest share of adjustment with a factor of 7.

4.3. Short-term dynamics: estimation of a vector error correction model

In cointegration analysis, unlike traditional econometric approaches ,short-term and long-term structures are explicitly separated from each other. The short-term error correction model is considered a feedback mechanism according to which the dependent variable of recycled paper demand is adjusted for the disequilibrium of the system. In fact, the aforementioned feedback mechanism ensures the achievement of a long-term equilibrium relationship. The Granger representation theorem refers to the same issue. According to this theorem, a long-term equilibrium relationship between a set of variables requires a short-term error correction model. This has a purely statistical basis and has nothing to do with economic theories. The error correction equation for the demand for recycled paper is generally specified as follows:

$$\Delta LnCR = \gamma_0 + \gamma_1 \sum_i \gamma_{1i} \Delta LnGDP_{t-i} + \gamma_2 \sum_i \gamma_{2i} \Delta LnCP_{t-i} + \gamma_3 \sum_i \gamma_{3i} \Delta LnPR_{t-i} + \gamma_4 \sum_i \gamma_{4i} \Delta LnCP_{t-i} + \gamma_{5i} DUM + ecm(-1) + V_t$$

The short-term error correction model results are also shown in Table 6.

Table (6) ECM for the Recycled Paper Demand Equation

Dependent variable=Δ LnCR			
Regressor	**Parameter estimate**	**t-ratio**	**P-values**
Intercept	0.003	0.383	0.702
Δ(LnGDP)	0.294	6.303	0.000
Δ(LnCP)	0.219	8.299	0.000
Δ(LnPR)	0.049	5.868	0.000
Δ(LnInternet)	-0.193	-0.979	0.331
DUM	0.036	2.828	0.006
EC(-1)	-0.510	-3.637	0.000

AdjR^2=0.91 D.W= 1.62 Serial Correlation LM Test=5.35 (0.14) RESET= 2.64(0.10) Normality= 1.53(0.46) White Heteroskedasticity Test=16.23 (0.21) Heteroskedasticity Test: Breusch-Pagan-Godfrey:1.83(0.15) Ramsey RESET Test:2.39(0.13)			

Note: Figures in bracket indicate p-values

Error correction models (ECMs) offer the distinct advantages of explicitly separating short-term and long-term parameters, and enabling the analysis of results based on the ECM coefficient.

Table (6) presents a summary of the ECM. The coefficients in this table are not interpretable, and only the short-run causal relationship can be observed.

The existence of cointegration among a set of economic variables provides a statistical (but not theoretical) basis for using the ECM. In other words, a long-run equilibrium relationship between a number of variables implies the existence of an ECM, and this has nothing to do with economic theories**.** Conversely, if we believe that an error correction model should be used for economic variables, then those variables are necessarily cointegrated.

As can be seen in the table, the ECM coefficient is estimated to be -0.51. This coefficient indicates that only -0.51% of the short-run disequilibrium moves towards long-run equilibrium from one period to the next.

As shown in Table 7, and given that both the centered VIF and the uncentered VIF values for the independent variables are less than 10, there is no multicollinearity among the independent variables.

Tabl (7):Variance Inflation Factor(VIF)

Variable	Coefficient Variance	Uncetered VIF	Centered VIF
C	0.000101	2.210469	NA
Δ(LOGGDP)	0.002186	2.117345	2.096908
Δ(LOGCP)	0.000698	1.124919	1.118779
Δ(LOGPR)	7.24E-05	1.510997	1.510885
Δ(LOGINTERNET)	0.039168	2.018027	1.058088
DUM	0.000165	1.194555	1.068592

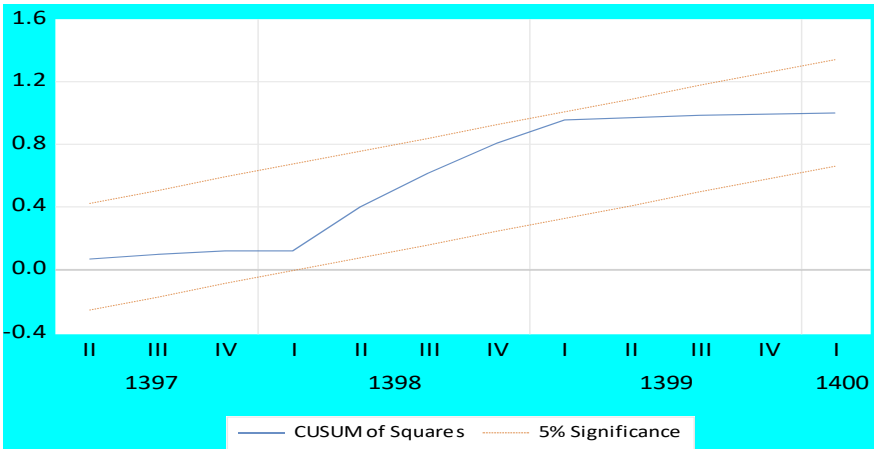

Figure 1: CUSUM of Squares

As Figure 1 illustrates, the blue plot remains within the confidence bands, indicating model stability

4.4. Variance decompositions and impulse responses functions

By decomposing the forecast variance, the proportion of variability in each variable attributable to shocks to other variables is determined. Furthermore, by decomposing the forecast error variance, the impact of each variable on the forecast horizon can be measured.

Testing the significance of the coefficients of lagged variables and error correction terms based on the vector error correction model (VECM). As mentioned, the Granger causality test is interpreted within the sample. Therefore, this test only determines the exogeneity or endogeneity of the dependent variable in the Granger sense within the sample period, but does not provide information about the dynamic properties of the system. The dynamic interactions of shocks created in the system are analyzed using variance decomposition (VDCS) and impulse response functions (IRFS). method measures the relative strength of the Granger causality chain or the degree of exogeneity of the variables beyond the sample period. Therefore, VDCS can be called an out-of-sample causality test. In this method, the contribution of shocks to different variables in the system is determined in the variance of the short-term and long-term forecast error of a variable. For example, if a variable can be optimally predicted based on its own lagged values, then the variance of the forecast error is decomposed into the share of each variable's fluctuations in response to shocks to the model variables. This allows us to measure the impact of each variable on the changes of other variables over time.

Table (8) Decomposition of the forecast error of the recycled paper demand variable

Internet logarithm	The logarithm of the price of printing and writing paper	logarithm of GDP	The logarithm of the price of recycled paper	The logarithm of demand for recycled paper	Season
0.000000	0.000000	0.000000	0.000000	100.0000	1
0.015789	0.142852	0.160456	0.807884	98.87302	2
0.095258	0.199266	0.478473	1.833686	97.39332	3
0.258286	0.231588	0.882408	2.734091	95.89363	4
0.504552	0.239171	1.257655	3.424769	94.57385	5
0.826470	0.226314	1.541047	3.915809	93.49036	6
1.209143	0.200340	1.718153	4.250954	92.62141	7
1.630065	0.170959	1.806851	4.478949	91.91318	8
2.063460	0.145899	1.836120	4.641057	91.31346	9
2.486401	0.128742	1.832549	4.767248	90.78506	10
2.883239	0.119477	1.815166	4.876533	90.30559	11
3.246692	0.116346	1.795376	4.978967	89.86262	12
3.576167	0.117403	1.778667	5.078246	89.44952	13
3.874898	0.121215	1.766569	5.174367	89.06295	14
4.147333	0.126923	1.758443	5.265880	88.70142	15
4.397500	0.134046	1.752877	5.351355	88.36422	16
4.628370	0.142269	1.748571	5.430039	88.05075	17
4.841914	0.151322	1.744693	5.501914	87.76016	18
5.039451	0.160938	1.740885	5.567469	87.49126	19
5.222017	0.170851	1.737108	5.627418	87.24261	20
7.071122	0.310835	1.700836	6.233013	84.68419	40

Table (8): Decomposition of the forecast error of the recycled paper demand variable for 40 seasonal periods or 20 years. The share of each of the system variables in the changes of the recycled paper demand variable in the short term of four seasons or the first year, the medium term of the second year, the fifth period to the fifth year (20), and the long term from the fifth year, period 20 onwards, is shown. As can be seen, the fluctuations in the demand for recycled paper are mainly explained by the variable itself at different time horizons. In fact, in the short term, 95% of the variance of the forecast error of recycled paper demand is explained in the short term. In the medium and long term, 87% and 84% of the variance of the forecast error is explained by the demand for recycled paper, respectively.

The recycled paper price variable is the second most important variable, explaining 2.7% of the variance of the forecast error of recycled paper demand in the short term, 5.6% in the medium term, and 6.2% in the long term.

Consequently, recycled paper exhibits greater sensitivity to fluctuations in paper prices over the long term compared to the short term.

In the short term, GDP with 0.88 percent in the medium term, 1.73 percent and in the long term, 1.7 percent is the third priority.
In the fourth place, the internet with 0.25 percent in the short term, 5.2 percent in the medium term and 7 percent in the long term explains the error in forecasting the demand for recycled paper. Theprice of printing and writing paper is the fifth most important variable, explaining 0.23% of the forecast error variance of recycled paper demand in the short term, 0.1708% in the medium term, and 0.31% in the long term.
Impulse response functions (IRFs) are a moving average representation of the dynamics of a VAR or VECM model, similar to VDCs. IRFs show the dynamic behavior of the model's variables over time in response to a unit shock or impulse to each of the variables. These shocks are typically chosen to be the size of one standard deviation, hence they are called unit shocks or impulses. The origin of the coordinate system or the starting point of the movement of the response variable is the value corresponding to the steady state of the system without the presence of a shockThe impulse response function (IRF) can be used to trace the evolution of a model's variables in reaction to a shock in one or more variables. This feature allows to assess the dynamic effects of shocks to a system.

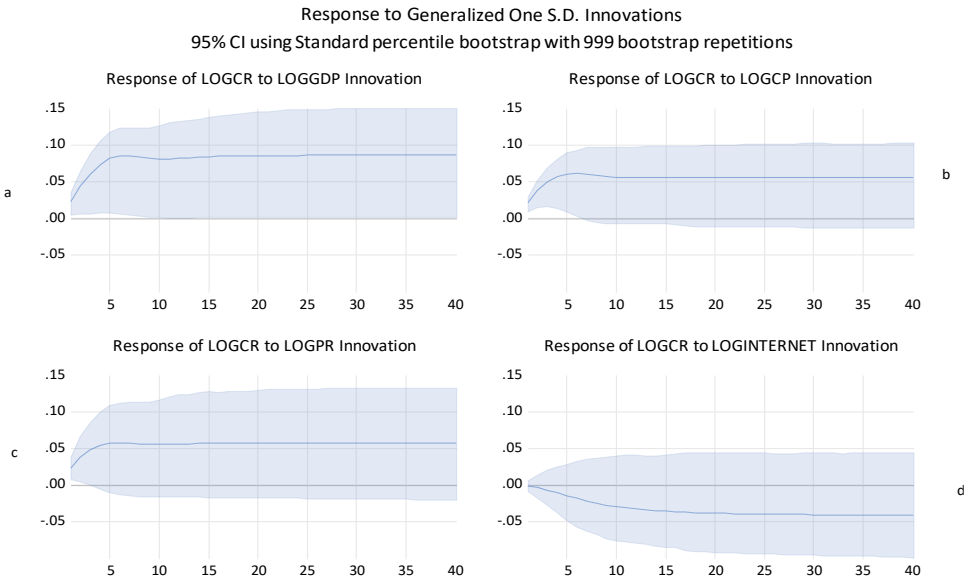

Figure 2: Generalized Impulse Response Functions to a Shock in Recycled Paper Demand

Since the contemporaneous response functions are sensitive to the ordering of the variables, the Pesaran and Shin (1998) impulse response functions are used here as well. Figure (2) shows the impact of a one-standard deviation shock to the model variables on the demand for recycled paper. As can be seen in Figure (2a),

following a shock to GDP, the demand for recycled paper increases by 2.3% in the first period and rises above the baseline level without shock. After that, the demand for recycled paper reaches its maximum value in the seventh period, 8.5% higher than the old baseline equilibrium. The effect of the shock on the recycled paper demand variable, with some fluctuations, dissipates and reaches a steady state at 8.6% above the horizontal axis in the long run.

In Figure (2b), the impact of the shock of the price of printing and writing paper on the demand for recycled paper in the first period is 2.1 percent. Such that its effect is positive and higher than the baseline.The increasing effect of the shock of the price of printing and writing paper continues until the sixth period and reaches its maximum value of ١،٦ percent.The effect of this shock in the long run reaches a stable level of ٥،٥percent.The effect of the shock of the price of recycled paper on the demand for recycled paper is shown in Figure (2c)The effect of the said shock in the first period is ٢،٣ percent higher than the baseline.After this period, the effect of the said shock on the demand for recycled paper in the sixth period increases to its maximum value of ٥،٧ percent higher than the old equilibrium state .After that, the shock of the price of recycled paper on the variable of demand for recycled paper disappears in the long run and becomes stable at ٥،٧ percent along the horizontal line .In Figure (2d), the effect of the internet shock on the variable of demand for recycled paper in the first period reduces this variable by ٠،١٨ percent and below the baseline.This decrease continues until the twenty-fourth period, reaching ٣،٩percent lower than the old equilibrium state, and then gradually disappears in the long run and stabilizes at ٤percent lower than the baseline along the horizontal line.

Based on the analysis of VDCS and IRFS, it can be concluded that in order to control the demand for recycled paper, price policies can be emphasized
in the first place in the short term, and on the other hand, in the long term, the infrastructure of Internet users can be facilitated.

Today, recycled paper is a key raw material for paper production and an economical option compared to wood as a raw material (Kumar Pati et al., 2006). in recent decades, the Internet, along with information and communication technologies such as personal computers and mobile phones, has become an electronic substitute for newspapers and printed materials (Greg et al., 2016).

Based on the theoretical and empirical foundations of the demand function, the factors affecting recycled paper were determined in order of gross domestic product, recycled paper price, the price of printing and writing paper and the Internet were determined, which were evaluated using the cointegration method for long-term and short-term relationships. The long-term results of all variables haveThe expected and significant effects on the demand for recycled paper are observed in this relationship. It is observed that recycled paper is a recycled paper is an inferior commodity. On the other hand, in the short term, the ECM

coefficient is negative and it was estimated to be 23, which indicates that 23% of the imbalance is eliminated from one period to the next and tends towards the long-term relationship.

The long-term income elasticity of demand for recycled paper is estimated to be -0/46%. In other words, as economic activity increases, the consumption of recycled paper decreases, indicating that recycled paper is an inferior good. Given the relatively low proportion of recycled paper in the production process, it is expected that as producers' incomes rise, they will use a smaller proportion of recycled paper. An input is considered inferior if, as a producer's purchasing power increases, the quantity of that input used in production decreases. In essence, this suggests that some inputs can be substituted for others in the production process, making the inferior status of recycled paper a plausible outcome. Additionally, as consumers' incomes increase, they tend to favor higher-quality products over recycled paper.

Given the price elasticity of demand for recycled paper is less than one, indicating a relatively inelastic demand, changes in the price of recycled paper have a minimal impact on the quantity demanded. Consumers appear to prioritize maximizing their utility from the essential commodity.

The long-term coefficient of printing and writing paper indicates a substitution effect for recycled paper. However, the small magnitude of this coefficient suggests that printing and writing paper is not a strong substitute for recycled paper. This is due to the broader range of applications for recycled paper, which includes cardboard, corrugated board, newspapers, tissue paper, and other paper products. Conversely, printing and writing paper has more specific uses.

The expanding use of the internet and personal computers has resulted in a heightened consumption of office paper. In tandem, the surge in online shopping and long-term demand have necessitated an increased use of packaging paper, cardboard, and corrugated board for shipping custom items, thus stimulating the demand for paper recycling.

These findings align with those of Hujala (2011), the FAO (2007), and Kong and Lu (2021). The results of this study corroborate the findings of Hetemaki and Hurmekoski (2017), who argued that the trade of forest products is influenced by gross domestic product and prices.

The results of the variance analysis (VDCS) show that the demand for recycled paper in the short term is affected by changes in gross domestic product and the price of recycled paper and the Internet.

The results of the impulse response functions (IRFS) are in line with the results of VDCS, so that shocks to gross domestic product and the price of recycled paper it plays a decisive role for it.

5. Conclusion and Recommendations

Based on the analyses conducted, the findings of this study indicate that the demand for recycled paper in the long run is influenced by macroeconomic factors such as Gross Domestic Product (GDP), the price of recycled paper, and the price of printing and writing paper. In this long-term relationship, recycled paper is identified as an inferior good, meaning that as economic activity and income increase, its consumption decreases. This is likely due to the preference of producers and consumers for higher-quality raw materials over recycled paper.

The price elasticity of demand for recycled paper was found to be less than one, indicating a relatively inelastic demand. This suggests that price changes have a limited impact on the quantity demanded. Furthermore, while printing and writing paper acts as a substitute for recycled paper, its small coefficient indicates that it is not a strong substitute. This can be attributed to the broader range of applications for recycled paper, which includes the production of products like cardboard, corrugated board, and tissue paper.

In the short term, the results show that the ECM coefficient is negative at 23%, which suggests that 23% of the imbalance from one period is corrected and adjusts towards the long-term relationship. The VDCS and IRFS analyses confirm that in the short term, changes in GDP, the price of recycled paper, and the expansion of the Internet play a significant role in determining the demand for recycled paper. While the Internet has reduced the demand for newspapers, the rise of online shopping has increased the demand for packaging materials like cardboard and corrugated board, thereby stimulating the demand for paper recycling. These findings are consistent with previous research in the field.

Recommendations:

- **Price Policies:** Given the VDCS and IRFS analyses, price policies can be an effective tool for controlling short-term demand for recycled paper[11].
- **Internet Infrastructure:** In the long term, demand for recycled paper can be influenced by facilitating internet infrastructure[12]. Since the internet acts as an electronic substitute for printed materials, its development can affect consumption patterns. Furthermore, considering the increased demand for packaging paper due to online shopping, policymakers can focus on managing this sector.
- **Recycling Industry Development:** As recycled paper is considered an inferior good, and its consumption decreases with rising incomes, policymakers can increase its appeal to producers and consumers by encouraging the use of new technologies and improving the quality of recycling processes. This can help increase the share of recycled paper in the production process and reduce reliance on virgin wood fiber

Conflict interests:

The authors declares that there are no conflict of interest regarding this article.

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تخمین تابع تقاضای کاغذ بازیافتی در ایران: رویکرد همجمعی

چکیده:

این پژوهش با هدف تخمین تابع تقاضای کاغذ بازیافتی در اقتصاد ایران طی دوره فصلی ۲۰۰۲ تا ۲۰۲۱ انجام شده است. روش مورد استفاده، هم‌انباشتگی جوهانسن–جوسیلیوس است تا عوامل مؤثر بر تقاضا را در بلندمدت و کوتاه‌مدت شناسایی کند. داده‌های فصلی با استفاده از روش دنتون از داده‌های سالانه استخراج شده‌اند و مدل به صورت لگاریتمی خطی مشخص شده است.

متغیرهای مدل شامل مصرف سرانه کاغذ بازیافتی، قیمت آن، قیمت کاغذ بکر، درصد کاربران اینترنت و تولید ناخالص داخلی (GDP) هستند. یک متغیر مجازی نیز برای لحاظ کردن حذف تعرفه واردات در سال ۲۰۱۸ به کار رفته است. نتایج نشان می‌دهند که کاغذ بازیافتی یک کالای ضروری و بی‌کشش است. در بلندمدت، با افزایش درآمد و رفاه، به یک کالای پست تر تبدیل می‌شود؛ به این معنا که مصرف‌کنندگان و تولیدکنندگان به سمت استفاده از کاغذ بکر با کیفیت بالاتر سوق پیدا می‌کنند.

در کوتاه‌مدت، تقاضا تحت تاثیر تغییرات GDP، قیمت کاغذ بازیافتی و اینترنت قرار دارد. کشش قیمتی تقاضا بسیار پایین (۰,۰۱۲٪) است که نشان‌دهنده تاثیر ناچیز قیمت بر مقدار تقاضا است. ضریب تصحیح خطا (ECM) با مقدار ۰,۵۱- حاکی از آن است که نیمی از عدم تعادل کوتاه‌مدت در هر دوره اصلاح می‌شود.

این یافته‌ها بر اهمیت سیاست‌های دولتی در تشویق بازیافت و مدیریت بازار تاکید دارند. با توجه به محدودیت منابع جنگلی، توجه به این بخش می‌تواند به پایداری اقتصادی و محیط زیستی کمک کند. در آینده، می‌توان تاثیر سیاست‌های مالیاتی و یارانه‌ای بر صنعت بازیافت کاغذ را بررسی کرد.

کلمات کلیدی: ایران، تابع تقاضا، تولید ناخالص داخلی، کاغذ بازیافتی، مدل VAR.