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China's Belt and Road Initiative and the Rise of Yuan – Evidence from Pakistan

Jamshed Y. Uppal* **and Syeda Rabab Mudakkar****

Abstract

The Chinese yuan is poised to become an international currency and play a major role in global finance which will have significant consequences for countries, like Pakistan, which have recently seen large inflows of the Chinese capital. This paper presents empirical evidence of the evolving nature of the yuan, as reflected in the statistical distribution of the exchange rate, with a particular focus on the period after the initiation of Belt and Road Initiative (BRI) projects. We observe that the currency's empirical distribution exhibits tell-tale characteristics of a managed currency. Over time, though the yuan's statistical properties have converged towards those of other hard currencies, they still remain distinct. We find that there is a long-term trend of increasing correlations over time as indicated by the Dynamic Conditional Correlations (DCC), which is pronounced in the post BRI period. Furthermore, the yuan is increasingly being influenced by other major currencies in the recent periods, indicating increasingly integration of the currency in global foreign exchange markets. This article discusses the implications of the rise of the yuan for the management of Pakistan's foreign currency reserves and exchange rate: it should be driven by the Yuan's evolving convertibility, credibility and liquidity.

Keywords: International currency, global finance, yuan, Pakistan.

JEL Classifications: F31, F39.

1. Introduction

The Chinese yuan is poised to become an international currency and play a major role in global finance, competing with other hard

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currencies to serve as a reserve currency, an intervention currency and a settlement currency. China's "One-Belt-One-Road" initiative (OBOR), later renamed as the Belt and Road Initiative (BRI), feeds into and strengthens this emerging role of the renminbi (CNY)[1]. Since the China-Pakistan Economic Corridor (CPEC), a major part of BRI, is expected to considerably increase the financial flows between the two countries, the rise of the renminbi (RMB) carries significant implications for the management of Pakistan's foreign currency reserves and exchange rate. In this paper we study how the yuan has evolved over time vis-à-vis other hard currencies, and how it has been affected by CPEC projects. The analysis provides policy implications for the management of the Pakistan's foreign exchange.

The renminbi is being used increasingly in settling cross-border trade and financial transactions, areas in which the US dollar has so far held the dominant position. Park (2016) reviews the reasons behind renminbi internationalization and highlights the Chinese government's strategy. At present, around 62 percent of China's foreign exchange reserves are denominated in USD and 20 percent are in EUR, which is in line with reserves holdings of other emerging market countries (Drut et al., 2016). The People's Bank of China (PBoC) has started to diversify its FX reserves by holding other currencies with a particular emphasis on Asian currencies. Also, the yuan is becoming an increasing component of foreign exchange reserves around the world, as a growing number of central banks and sovereign wealth funds include renminbi reserves and investments. Drut et al. (2016) suggest that the yuan already serves as an anchor currency for several countries. Shu, He, and Cheng (2014) present empirical evidence of the renminbi's growing influence in the Asia-Pacific region. Their findings also suggest that China's regional influence is increasingly transmitted through financial channels. Patel (2016) finds that the yuan has become a reference currency rivaling the US dollar in East Asia within the past decade and indicates that export similarity plays a major role in increasing regional currency influence.

[1] "renminbi" and "yuan"—are used interchangeably, the former is the official currency of the People's Republic of China and the latter is the name of the unit in which renminbi transactions are denominated. Yuan also refers to the currency generally. Its international symbol is CNY (or CNH in Hong Kong; but abbreviated RMB, with the symbol ¥).

The IMF's decision to include the renminbi (RMB) in the SDR basket effective October 1, 2016 not only symbolizes worldwide recognition of Chinese yuan as an international currency, but also carries implications for international finance. This decision boosted the credibility of the yuan and global demand for the Chinese currency (Hongcai, 2015). As a result, the share of the yuan as a reserve currency held by the foreign central banks will necessarily increase. Given that a current-account deficit is unlikely for China in the short run, it is inevitable that the yuan will continue to flow abroad through capital account deficits. On the other hand, Wang (2015) argues that "the inclusion of the Chinese currency in the SDR basket may well play a facilitating role in China's financial liberalization, but it does not in itself transform the yuan into a global reserve currency."

The emergence of the yuan as an international currency is likely to have major consequences particularly for countries with large inflows of the Chinese capital, as in the case with Pakistan under CPEC. The internationalization of the yuan will challenge the capacity of these countries to steer macro-economic policies and to manage financial risks. Drut et al. (2016) argue that "the USD never had a real contender in the past, and a tripolar system (USD, EUR and CNY), more precisely a system of competing international currencies, may be unstable during some periods." This instability arises essentially due to the capacity and incentives for investors, including the central banks, to shift the composition of their international portfolios and FX reserves. Park (2016) considers the ramifications of yuan internationalization and foresees the dawn of a multi-polar monetary system, whether or not the yuan would replace the dollar as the leading reserve currency.

This article presents empirical evidence on the evolving nature of the yuan, as reflected in the statistical distribution of the exchange rate, in particular since the initiation of BRI projects. The paper is organized as follows. Section 2 traces the regulatory developments in currency management by the Chinese authorities, which have facilitated a larger role of the currency in international finance. Section 3 begins with a description of the methodology and the data used in our empirical analysis. Section 4 presents descriptive statistics and presents the findings from the empirical exercise. The final section discusses the results and

draws implications for the management of exchange rates and foreign exchange risk from Pakistan's standpoint.

2. Renminbi Internationalization

China has moved towards greater exchange rate flexibility since 1994 when the multiple exchange rates for the renminbi were unified, and the yuan became fully convertible. More significantly, in July 2005 the People's Bank of China (PBoC) announced that China would implement a managed floating exchange rate system based on a basket of currencies, instead of pegging the yuanto the US dollar. The daily trading band against the US dollar has been progressively widened since then, from ±0.3to ±0.5 percent in May 2007, to ±1 percent in April 2010 and to ±2 percent in March 2014. In November 2013 the PBoC Governor announced that the central bank would withdraw over time from regular intervention in the market. At the same time, in July 2009 the Chinese authorities started facilitating the use of renminbi outside mainland China, by removing restrictions on the use of the renminbi in current account transactions (cross-border settlements) and gradually liberalizing its use in capital account transactions. Broader sources of offshore funds have been allowed for capital transactions, e.g., overseas direct investment in the renminbi by Chinese enterprises from 2011 and relaxation of rules to make offshore lending easier for the mainland banks. Bilateral local currency swap facilities have also been set up with overseas central banks and monetary authorities, which support the international use of the renminbi and provide a contingent source of liquidity.

The use of offshore renminbi has been officially sanctioned for a wider variety of transactions, such as in the onshore interbank bond market, foreign direct investment, and the renminbi Qualified Foreign Institutional Investor (R-QFII) scheme.[2] Technical measures have also been implemented to further market development. In June 2011, spot fixing for the offshore renminbi exchange rate was launched in Hong Kong SAR. In June 2013 interbank interest rate fixing for the renminbi (CNH- HIBOR), the first offshore renminbi interest rate benchmark, was

[2] Under the scheme, Hong Kong-based brokerage firms could offer renminbi investment products to non-Chinese residents that are invested in onshore bond and stock markets.

introduced. These measures have facilitated the development of renminbi products such as syndicated loans and cross-currency swaps, and vibrant offshore renminbi markets have emerged. Renminbi offshore centers are now well established in London, Singapore and other locations. As of June 2017, the PBoC has designated 23 official renminbi clearing and settlement banks around the world. Because of the rapid internationalization of the renminbi, according to the Society for Worldwide Interbank Financial Telecommunication (SWIFT),it became the world's 8th most traded currency in 2013, rising to the 5th position by 2015.On October 1, 2016, the yuan became the first emerging market currency to be included in the IMF's special drawing rights basket, the basket of currencies used by the IMF (reserve currency).

Maziad and Kang (2012) found that foreign access to yuan-denominated assets that could act as global stores of value remained limited due to extensive restrictions on capitals flows. However, theyfind that "the rapid expansion of RMB [yuan] trade settlement and issuance of RMB-denominated bonds by the Chinese government and corporates in Hong Kong SAR have created some feedback channels across onshore (CNY) and offshore (CNH) RMB markets." They also find evidence of volatility spillovers between the onshore (CNY) and offshore (CNH) yuan markets. Overtime, those spillover channels would be expected to grow as the offshore market further develops.

The most recent phase in the internationalization of the yuan was set into motion with the announcement of the "One Belt One Road Initiative" (OBOR) in September 2013 by China's President Xi Jinping. In 2014, the Silk Road Fund was established followed in 2015 by the Asian Infrastructure Investment Bank (AIIB). These initiatives are intended to play a significant role in financing infrastructure projects in sixty-eight countries. OBOR projects are to lead to increasing Chinese overseas investments and also to influence the selection of the currency used in those transactions.

Internationalization of the renminbi (CNY) has far-reaching implications for economic integration between China and its partners in the Belt and Road Initiative. For example, Fan at el. (2017) argue that yuan swap agreements are beneficial for economic integration between China and the Belt and Road countries through facilitating bilateral trade. This

carries implications for Pakistan's economy and its foreign exchange policies, since CPEC is a pivotal element in China's BRI.

3. Methodology and Data

a) Methodology:

The exchange rate structure of the yuan has transitioned from a fixed-rate regime to a free-floating regime. We first note from the extant empirical research, that "… there are substantial and systematic differences in the behavior of real exchange rates under these two nominal exchange rate regimes;" Mussa (1986). Genberg and Swoboda (2004) further document that the "properties of the frequency distribution of changes in exchange rates are different in countries that announce that they are following a fixed exchange rate regime compared to countries that are officially floating." More interestingly, the authors note that the properties of the tails of the distributions are different for the two foreign exchange regimes, i.e., the *de jure* fixed category contain a higher frequency of large exchange rate changes (of either sign) compared to the *de jure* float category. There is also a growing divergence between the *de facto* and *de jure* exchange rate regimes followed by the central banks - most countries now follow a *dirty float*.

Secondly, as Engel and Hakkio (1993) explain, the system of fixed but adjustable rates introduces a new kind of volatility: volatility caused by expectations of exchange rate realignments. By eliminating the market's uncertainty about the future exchange rate, a system of fixed exchange rates reduces *normal* volatility. However, when the rates are fixed but adjustable, the market knows that realignment may occur, the speculation around the magnitude and timing of the realignment will exacerbate exchange rate volatility. Therefore, between realignments the exchange rate volatility will tend to be within normal limits, but around the time of realignments it can be extreme. If the equilibrium rate continues to trend upward or downward, then the likelihood of realignment increases, as do incidences of extreme volatility. Therefore, we focus on the standard deviation and kurtosis of the distributions; the former denoting normal volatility and the later denoting extreme changes injected by realignment of the exchange rate under managed regimes.

The managed regimes are characterized by relatively low standard deviation, but large kurtosis.

Huang, (2016) finds that the USD/CNY exchange rate exhibits very different patterns in different periods, differing wildly from one period to another in response to the economic reforms and changes in policies. Different statistical models seem to perform well for describing and forecasting currency dynamics in different periods. Our research focuses on the statistical distributions and the time-series properties of the yuan exchange rate, in comparison to the Pakistan Rupee (PKR) exchange rate against four hard currencies, i.e., US dollar (USD), euro (EUR), British pound (GBP) and Japanese yen.

b) Study Period and Data:

The time period for the study starts after the Asian currency crisis of the late 1990's. The full sample period spans from January 1999 to August 2018, whereas the comparative analysis is conducted on three sub-periods. Period 1 spans the post-Global Financial crisis from July 2009 to June 2012 when the yuan was managed under a floating exchange rate regime. The period consists of 783 daily observations with gaps. Period 2 consists of July 2012 to June 2015 when the yuan was transitioning to the free-floating regime and the central bank was gradually withdrawing from intervention in the foreign exchange market. We call it the Pre-BRI period; it consists of 782 daily observations. Period 3 spans from July 2015 to August 2018 when yuan internationalization was pushed through Belt and Road Initiative/CPEC projects. We call it the BRI period (806 daily observations). The "returns" are measured as the first log differences of the exchange rate series i.e.:

$$R_{t,EUR} = \ln((EUR/PKR)_t / (EUR/PKR)_{t-1})$$

$$R_{t,USD} = \ln((USD/PKR)_t / (USD/PKR)_{t-1})$$

$$R_{t,GBP} = \ln((GBP/PKR)_t / (GBP/PKR)_{t-1})$$

$$R_{t,JPY} = \ln((JPY/PKR)_t / (JPY/PKR)_{t-1})$$

$$R_{t,CNY} = \ln((CNY/PKR)_t / (CNY/PKR)_{t-1})$$

The purpose of converting exchange rates into geometric returns is to achieve stationarity, which is confirmed by the results of the Augmented Dickey-Fuller tests (ADF) as reported in Table-1.

Table1: Augmented Dickey-Fuller Test (ADF)

R_t	EUR	USD	GBP	JPY	CNY
Chi-Squared-Statistic	-74.599***	-78.129***	-72.894***	-77.312***	-66.641***

Note: The null hypothesis assumes that the series has a unit root and *** indicates rejection of the null hypothesis at 1 percent level of significance.

Since the risks related to a foreign currency are reflected in the statistical distribution and time-series dynamics of the exchange rates, we examine the foreign exchange behavior estimating three different aspects: (i) Conditional Volatility (ii) Dynamic Conditional Correlation (iii) the influence of hard-currencies on the yuan.

i) Conditional Volatility

Time-varying volatility was first modelled as an Autoregressive Conditional Heteroskedasticity, ARCH (q), process (Bollerslev et al., 1992), which relates time t volatility to past squared returns up to q lags. The ARCH (q) model was later expanded to include dependencies up to p lags of past volatility. The expanded model, the Generalized Autoregressive Conditional Heteroskedasticity, the GARCH (p,q) model, has become the standard methodology to incorporate dynamic volatility in financial time series (see Poon and Granger, 2003). The auto-correlation of returns is significant in many cases and there is also a need to incorporate the Autoregressive Moving Average, ARMA (m,n), structure in the model. Our analysis of the data leads us to identify the AR(1)-GARCH(1,2) model as sufficient to capture conditional volatility for all currencies except the Chinese yuan where the AR(1)-GARCH(1,1) model seems to be appropriate. The GARCH(1,2) model is described as follows:

$$\sigma_t^2 = w + \alpha_1 \epsilon_{t-1}^2 + \alpha_2 \epsilon_{t-2}^2 + \beta_1 \sigma_{t-1}^2$$

With the necessary and sufficient conditions: $w > 0, 0 \leq \beta_1 < 1, \alpha_1 \geq 0$ and $\beta_1 \alpha_1 + \alpha_2 \geq 0$.

We first check the adequacy conditions (not reported here) over the full sample for all currencies. Next, the selected model is used to compare estimated coefficients across the post-GFC, pre-BRI and BRI time sub-periods and to compute the Dynamic Conditional Correlation, as explained below. The appropriateness of the selected model is supported by an examination of the standardized residuals for all cases. A comparison of the coefficients in the post-GFC, pre-BRI and BRI periods is conducted using the Wald chi-squared statistic by restricting the coefficients in one period in order to examine the suitability of the model in another period.

ii) *Dynamic Conditional Correlation*

A multivariate flexible GARCH model was introduced by Robert Engle in 1982 for analyzing dynamic correlations as well as volatilities. This Dynamic Conditional Correlation model (DCC) estimates the volatilities and correlations in two steps. In the first step, after applying the appropriate GARCH (p,q) models to each series, the standardized residuals from the model are extracted. In the second step, correlations are estimated between the standardized residuals with a smaller number of parameters. The specification of the correlation dynamics is extended to allow for asymmetries. In our study, the variable of interest is Chinese yuan(CNY); therefore, after extracting the standardized residuals from model of each series we compute the dynamic conditional correlation of CNY against the EUR,GBP, USD and JPY.

iii) Influence of hard currencies on the yuan

The influence of the major trading currencies on yuan is examined by ordinary least square estimation. The analysis is conducted separately for the full, post-GFC, pre-BRI and BRI periods. The appropriateness of the model is examined using residual analysis. Finally, the stability of coefficients in post-GFC, pre-BRI and BRI periods is analyzed using the Chow Breakpoint test, which tests for the presence of a structural break in the specified time period.

4. Empirical Results and Discussion

a) Descriptive Statistics

Table2 provides the descriptive statistics of the return series for the full, post-GFC, pre-BRI and BRI sample periods respectively. The average daily return for all series is positive, which reflects devaluation of PKR over the full sample period with respect to the other currencies.However, the rate of the PKR's depreciation has varied in different times, and in the pre-BRI period it has even appreciated against the EUR and JPY. Note that, since we are stating the exchange rate as rupees per unit of foreign currency, a positive change represents a loss in the value of rupee. The exchange rate returns in all five cases do not follow the normal distribution as is evident by the significant values of the Jarque-Bera statistic.

Table2: Summary Statistics

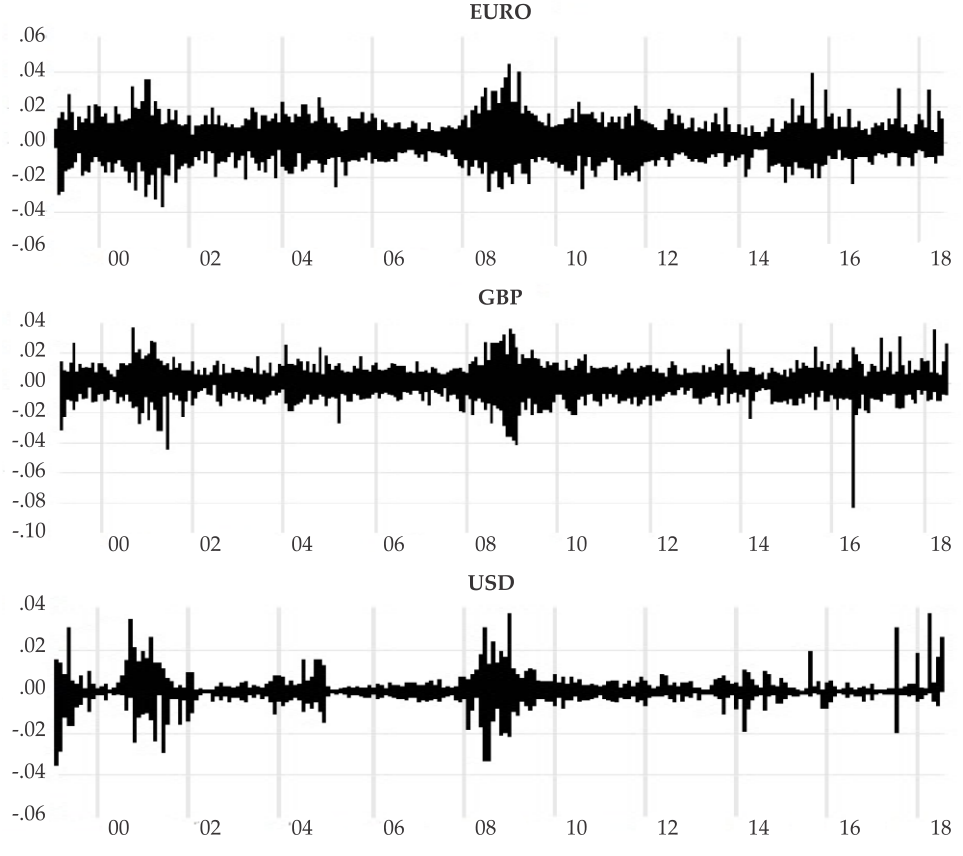
Period	FX	Mean* x1E+4	Max	Min	Std. Dev	Skewness	Kurtosis	Jarque-Bera
	EUR	0.180	0.045	-0.050	0.007	0.109	5.977	1889***
	GBP	1.300	0.037	-0.085	0.007	-0.574	11.972	17343***
Full Sample	JPY	1.800	0.083	-0.083	0.008	0.079	12.784	20299***
	USD	1.700	0.038	-0.054	0.003	0.042	41.745	318244***
	CNY	2.200	0.158	-0.158	0.006	0.027	297.271	18358249***
	EUR	1.050	0.040	-0.026	0.008	0.032	3.749	18***
	GBP	2.240	0.033	-0.042	0.008	-0.367	5.125	165***
Post-GFC Period	JPY	4.200	0.044	-0.036	0.007	-0.247	6.165	335***
	USD	1.820	0.037	-0.021	0.003	1.888	35.027	33930***
	CNY	2.800	0.014	-0.015	0.002	-0.435	8.248	923***
	EUR	-0.701	0.025	-0.023	0.006	-0.125	4.558	81***
	GBP	0.938	0.023	-0.023	0.005	-0.233	4.627	93***
Pre-BRI Period	JPY	-4.600	0.030	-0.029	0.007	-0.140	4.664	93***
	USD	0.938	0.010	-0.019	0.002	-1.724	21.036	10986***
	CNY	1.300	0.012	-0.021	0.002	-1.627	18.147	7821***
	EUR	3.000	0.040	-0.050	0.006	0.209	12.502	3038***
	GBP	0.172	0.036	-0.084	0.007	-1.937	28.393	22159***
BRI Period	JPY	0.180	0.047	-0.054	0.007	0.446	11.600	2510***
	USD	1.300	0.038	-0.054	0.004	-0.757	101.702	327252***
	CNY	1.800	0.037	-0.054	0.004	-0.735	56.163	94890***

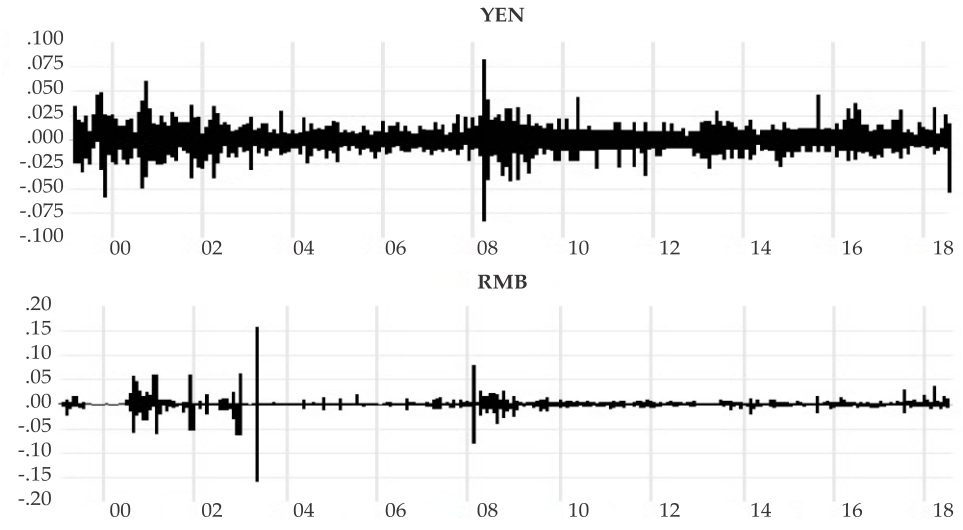
*Note: The null hypothesis of Jarque-Bera test statistic assumes that series follows a normal distribution. *** indicates the rejection of null hypothesis at 1 percent level of significance. We use EVIEWS 10.0 for the analysis.*

It is notable that the standard deviation of the daily exchange rate returns is the lowest for the yuan followed by that for thedollar; these

statistics are almost less than half of the standard deviations for the other currencies (EUR, GBP and JPY). On the other hand, while the returns series in all cases have excess kurtosis (measure > 3), which indicates the presence of outliers in daily exchange rate returns; the kurtosis statistics are the highest for the dollar and the yuan. In particular, theyuan has remarkably high kurtosis over the full sample period, which includes a period for which the currency was fully managed. This pattern is consistent with the observation that the managed exchange rates result in low standard deviation but high kurtosis. The USD/PKR exchange rate fits this pattern as well due to the rate being managed from the Pakistani side, while CNY/PKR exchange rate fits this pattern due to FX management on the part of the Chinese.

Figure 1: Daily Exchange Rate Returns against Pakistani Rupee (PKR)





From Table 2 we also observe that the kurtosis measures increased substantially for all currencies during the BRI sub-period as compared to the previous two sub-periods. The highest value of kurtosis indicates the frequent presence of abnormal daily exchange rate returns. This could be due to a number of extreme adjustments in the PKR exchange rate during the BRI period but may also indicate frequent adjustments in the exchange rate on the part of the Chinese authorities.

b) Empirical Results

i) Dynamics of Volatility

The next step is to estimate the dynamics of the conditional mean and volatility of the exchange rate series, as per the models laid out in the previous section. Figure 1 shows the daily returns for the five exchange rate return series. The graph indicates that large changes tend to be followed by large changes of either sign and small changes tend to be followed by small changes. It implies that the returns are not independent and identically distributed (i.i.d.), and the volatility clustering phenomenon is present in the data, which is also verfied by the correlogram of squared returns(not shown here). This suggests that GARCH modelsneed to be employed to incorporate dynamic volatility.

We report the results of the estimation in Table 3. As explained in the section 3b(i), our preliminary checks on the data lead us to identify the

AR(1)-GARCH (1,2) as the model to sufficiently capture conditional volatility for all currencies except for the yuan (CNY), in which case the AR(1)-GARCH (1,1) model seems appropriate. The Durbin-Watson statistic value (reported in Appendix) lies in the acceptable range in all cases. Although the significant Jarque-Bera statistic and kurtosis estimates indicate departure from normality and the presence of heavy tails in all cases (reported in Appendix), the insignificant p-values of the Autoregressive Conditional Heteroscedasticity-Lagrange Multiplier (ARCH-LM) statistic imply that extracted residuals from suggested models are i.i.d. This means that the suggested volatility models are appropriate and can be used for further analysis. The results are reported in Table4.

Our estimation of the GARCH models validates our initial assumption and shows that the dynamic volatility process followed by the CNY is quite different from the other hard currencies. It suggests that in the case of the yuan, exchange rate volatility subsides quicker than is the case with the other currencies, and hints at active management of the exchange rate. Comparing the volatility dynamics of the five exchange rate returns, the results imply that, in general, the ambient volatility is highest in the case of the yuan against the Pakistani rupee and the least in the case of USD as indicated by the estimated constant for the full sample period. There are a few exceptions to this observation, for example, in case of EUR in the BRI period, and EUR and JPY in the post-GFC period.

When comparing the pre-BRI and the BRI period, we observe an increase in the ambient volatility during the BRI period for all currencies. The dependence of average returns on its immediate past is highly significant (p-value <0.001) in all cases for the full sample period, but the coefficient on the average daily return is significant only for the USD and the yuan during the pre-BRI and the BRI periods. This result could be due to the increase in circulation of the yuan during the BRI period.

The significant value of the first two coefficients of the ARCH effect indicates that the previous two days' shocks have impacts on the current volatility of exchange rate returns for the full sample period in all currencies, except for the yuan, in which case the coefficient is significant for lag 1 only. The impact of the immediate shock on the current volatility is the highest for the yuan, followed by the USD during the full sample period. Comparing the pre-BRI period, the impact of the last lag on

current volatility is the highest for the USD. However, in the BRI period, the increase in ARCH lag 1 effect is highest for the yuan, followed by the USD. This indicates an increased impact of the yuan on the Pakistani rupee during the BRI period.

Figure 2 presents the conditional standard deviations obtained from the fitted GARCH model for the five exchange rates. It appears that the yuan's conditional standard deviation has followed a different pattern than the other four exchange rates. In the case of the USD, the model indicates that although there are spikes during 2000-2002, 2008-2010 and post-2017, the exchange rate seems to fair better in reverting back to its average variation of around 0.003 (less than EUR). In the case of the yen, we observe fluctuations in volatility throughout the period. On the other hand, in the yuan's case, the average variation is very low, around 0.0005 throughout the sample period. However, the standard deviation seems to shift abruptly with sharp spikes; for example, during 2003 the conditional variation shows a spike of 0.11 and in 2008 approximately of 0.05.

Table3: Coefficients Extracted from GARCH Analysis

Period	FX	Mean Equation		Variance Equation			
		μ	φ_1	w	a_1	a_2	b_1
		Mean	**1st Lag**	**Constant**	**(ARCH)**	**(ARCH)**	**(GARCH)**
Full Sample	EURO	20.000**	-0.054***	0.020***	0.056***	-0.030	0.970***
	GBP	20.000**	-0.045***	0.029***	0.132***	-0.101***	0.963***
	JPY	9.210	-0.083	0.064	0.104	-0.068	0.955
	USD	9.290***	-0.253***	0.005***	0.378***	-0.354***	0.971***
	CNY	24.000***	-0.142***	1.140***	0.441***		0.249***
Post-GFC Period	EURO	14.000	-0.035	4.390	0.133**	0.044	0.179
	GBP	10.000	-0.072**	0.070***	-0.057**	0.062**	0.976***
	JPY	45.000	-0.057	3.550**	0.034	0.076**	0.252
	USD	10.000	-0.218***	0.017***	0.179***	-0.093*	0.883***
	CNY	31.000***	-0.140***	0.243***	0.124***		0.469***
Pre-BRI Period	EURO	-0.795	-0.046	0.041***	0.118***	-0.080	0.949***
	GBP	10.000	-0.007	0.081	0.112***	-0.073**	0.927***
	JPY	-30.000	-0.106***	0.074***	0.134***	-0.094**	0.942***
	USD	10.000***	-0.092**	0.005***	0.483***	-0.315***	0.858***
	CNY	26.000***	-0.047	0.089***	0.325***		0.516***
BRI Period	EURO	26.000	0.019	3.500***	0.068***	0.217***	-0.171
	GBP	-2.520	-0.061	0.409**	0.404***	-0.318***	0.854***
	JPY	30.000	-0.041	0.369***	0.122***	-0.073**	0.884***
	USD	38.000***	-0.213***	0.299**	0.580***	-0.309**	0.510**
	CNY	22.000**	-0.085*	0.907***	0.668***		0.018

*** and **** indicates significance at 5 and 1 percent level of significance respectively.*

Figure 2: Dynamic Volatility of Exchange Rate return against Pakistani Rupee (PKR)

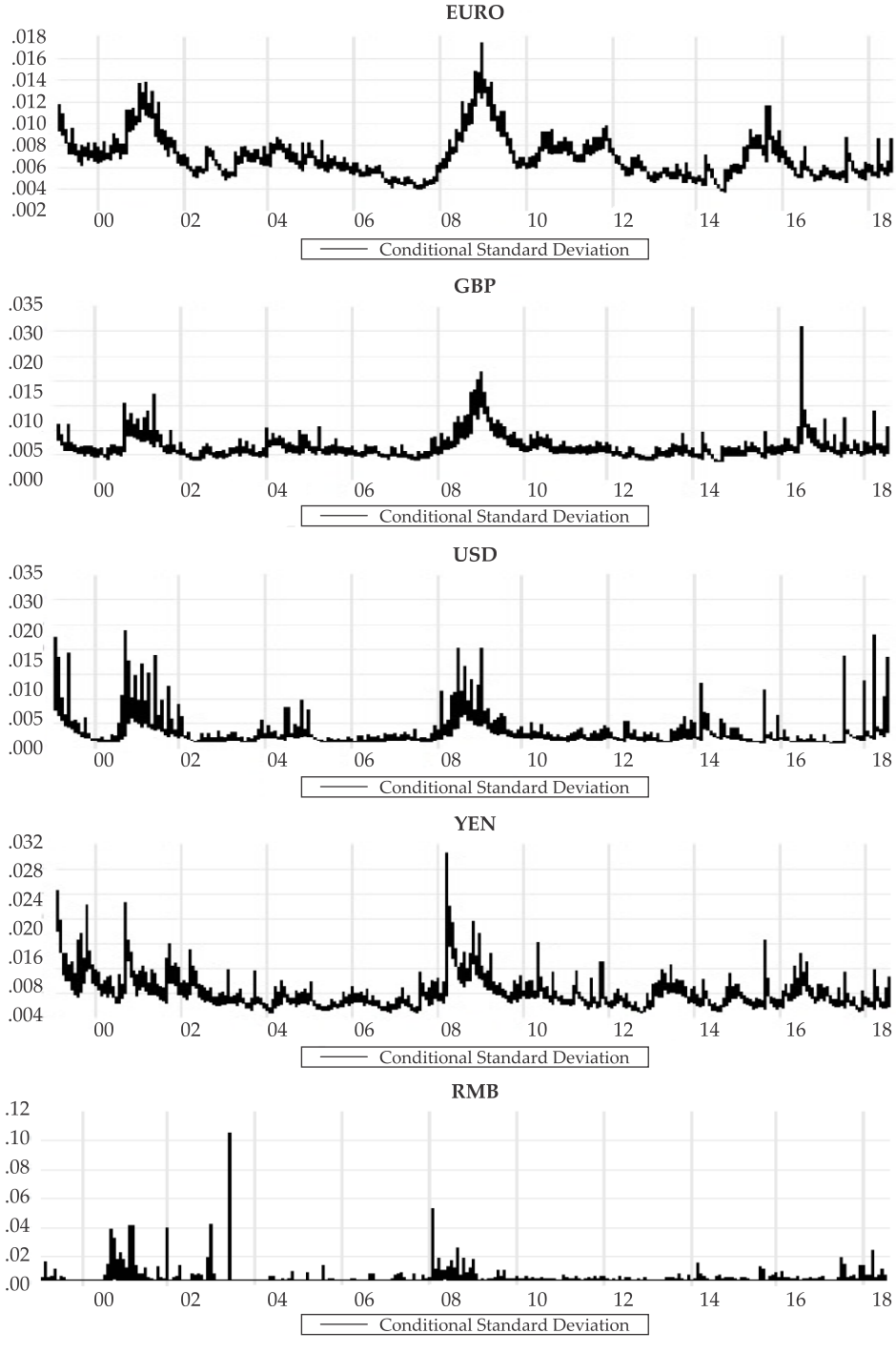


Table4: ARCH LM residual test

Period	Full Sample	Post GFC	Pre-BRI	BRI
EUR	0.2055	2.5651	0.0443	0.0536
GBP	0.0077	0.0407	0.0069	0.1034
USD	0.0005	0.0115	0.3637	0.0001
JPY	0.0681	0.0307	0.0083	0.0196
CNY	0.0018	0.5006	0.2380	0.0317

F-statistic values are reported in the cells which test the null hypothesis that the residuals extracted from the fitted models are independent identically distributed (i.i.d.).

Next, we run Wald tests to examine the stability of coefficients across post-Global Financial Crisis, and across the pre-BRI and the BRI period to make comparisons. The results are reported in Table5. We impose the restriction of coefficients being equal in both periods for all cases. We find that, for all currencies, the Wald test statistics reject the null hypothesis that GARCH model coefficients are equal across the periods. This indicates that the estimated coefficients during the pre-BRI period cannot be used during the BRI period. The results underscore the differences in volatility structure during the post-Global Financial Crisis period, the pre-BRI-period and the BRI period.

Table 5: Wald Chi Squared Test

	EUR	GBP	USD	JPY	CNY
Post-GFC and Pre-BRI	60.0328***	32.175***	8.997**	6.3330**	40.3507***
Pre-BRI and BRI	10383.4***	331.4364***	38861.16***	108.1362***	109.9875***
Post-GFC and BRI	21841.94***	284.4242***	1529.18***	5.2591**	1169.24***

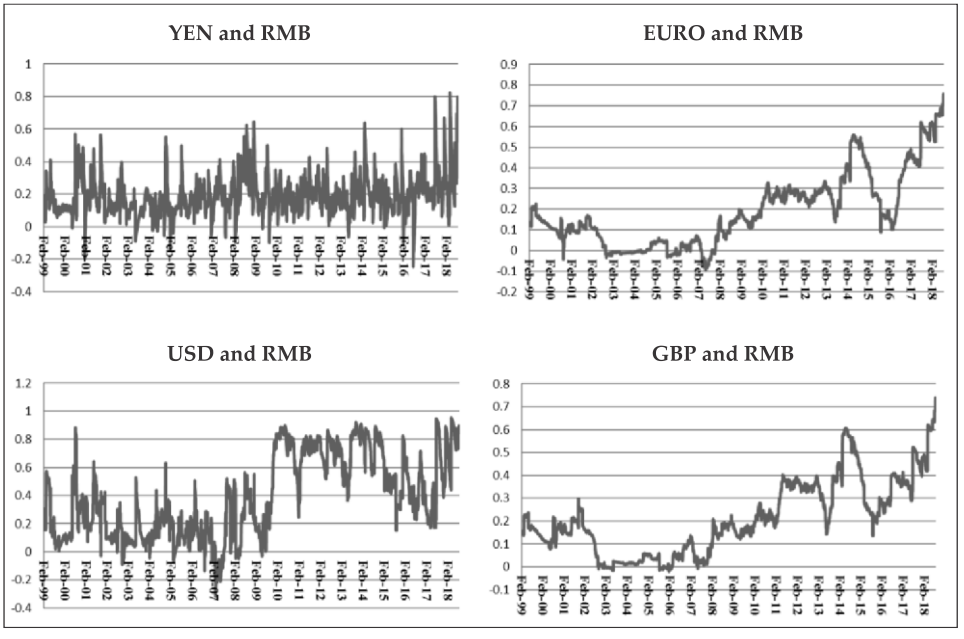
*Chi-squared statistic values are reported in the cells which test the null hypothesis of structural stability of model in one period compared to another period. ** and *** indicate significance, and rejection of null hypothesis at 5 and 1 percent level of significance respectively*

ii) Dynamic Conditional Correlation

Once the univariate GARCH model is fitted, we employ multivariate GARCH models to compute time-varying correlations of the yuan with the other currencies. In the case of yen and yuan, we observe a low positive correlation in the range of 0.2, although there are occasional jumps (as in 2000) when the currency pair correlation jumps to 0.6. Interestingly, in the BRI period we observe that the yen and yuan exhibit strong positive correlations upto 0.8.

In the case of the EUR and CNY, during the 2001-2003 period the currency pairs show decreasing correlation, followed by almost no correlation during the 2003-2007 period. In the following period, 2008-2014, the currency pair correlations steadily increase to 0.60. Then, there is a period of decline in correlations which drop to approximately0.1 in 2014-2015. Finally, during the BRI period the correlations between EUR and CNY are positive and increasing. It points to the emergence of the yuan in the BRI period as an international player, significantly affecting exchange rate movements of the EUR/PKR rate. The correlation behavior of the yuan with GBP is similar to that with the EUR. Until 2003, the correlations are decreasing, reaching almost zero during 2003-2006 but increasing afterwards, until 2014. During 2014-2016, the correlation decreased abruptly but then steadily increased to 0.70 in 2018. This indicates that during the BRI period, the yuan seems to be affecting the GBP/PKR exchange rate. The dynamic conditional correlation between the USD and CNY follows a different pattern. The graph indicates that currency pair correlations exhibit considerable fluctuations throughout the sample period. Interestingly, whenever the correlation exhibits a positive jump, it seems to be followed by a reversion downwards. The phenomenon could also be an indication of the corrective action of China's central bank on the yuan exchange rate. During 2001, there is a positive spike in the pair's correlation to 0.9, but the correlation falls back to about 0.2 in 2002. Similar behavior continues until 2006 with upward and downward spikes. In 2007 we observe a negative correlation between the currency pairs of -0.3, and throughout the Global Financial Crisis (2007-09) period, wide fluctuations in the correlation ranging from 0 to 0.6 are seen. Interestingly after 2009, we observe a structural upward shift in the correlation to a maximum of 0.8 which lasts until 2015. However, in the BRI period, the currency pair-correlations again exhibit an unstable pattern, ranging from 0.2 to 0.95. The increase in correlation post-GFC could be an indication that the yuan is being used increasingly in Pakistan for settling cross-border trade and financial transactions, along with the US dollar.

Figure 3: Dynamic Conditional Correlation



iii) Influence of hard currencies on yuan

Next, we examine how the exchange rate of the Chinese yuan (CNY) is being influenced by major currencies as is explained in section 3b (3). In these models, residuals extracted from the fitted GARCH models are employed in multiple-regressions, with the CNY residuals as the dependent variable. The results of the OLS estimations are reported in Table 5.

During the full sample period, we observe that all hard currencies except EUR have a significant impact on the exchange rate of CNY against PKR. The impact of USD is the highest followed by YEN and GBP respectively. However, only 12.7 percent of the variation of the yuan is explained by three major trading currencies during 1999-2018. Considering the sub-periods, post-Global Financial Crisis period (2009-2012), 24.7 percent of the variation in the CNY/PKR rate is explained by USD and YEN only. The impact of USD is the highest followed by YEN, whereas the impact of all other currencies is insignificant. Comparing the pre-BRI and the BRI period results, we observe that during pre-BRI period almost 82 percent of the variation of the CNY is explained by the

USD only (indicated by the only significant coefficient). During the BRI period the impact of USD on CNY remains significant but it is somewhat reduced (coefficient value is 0.8318); however, the coefficients of GBP, EURO and YEN are now also significant. The four currencies together explain 73.3 percent of the variation in the yuan during this period. This points to China's increasing regional influence, which seems to be transmitted through foreign exchange markets after 2015. The values of the Durbin-Watson statistic are tenable in all cases which speak to the appropriateness of the model.

Table 6: Multiple Regression Analysis (Dependent variable CNY)

Independent Variables	Full Sample	Post GFC	Pre-BRI	BRI
Constant	0.0001*	0.0002**	3.55E-05	-0.00011
	(1.6504)	(2.5223)	(0.9524)	(-1.4110)
EUR	-0.0198	0.01256	0.0019	0.0501***
	(-1.3161)	(0.9509)	(0.2112)	(2.6548)
GBP	0.0408**	0.00052	-0.0044	0.0651***
	(2.5268)	(0.0359)	(-0.4019)	(4.6881)
USD	0.3839***	0.3516***	0.9964***	0.8318***
	(14.9547)	(12.3342)	(50.6109)	(30.5486)
JPY	0.1451***	0.05173***	0.0077	0.0352**
	(15.4149)	(4.9095)	(1.2760)	(2.5674)
Adjusted R Sq.	0.1267	0.2466	0.8176	0.7327
No. of observations	5088	783	782	806
Durbin Watson	2.811	2.4503	2.011	1.922

Note: The t-statistic value which tests the significance of the coefficients is reported in parenthesis. *,** and *** indicates the rejection of null hypothesis at 10 percent, 5 percent and 1 percent level of significance.

An important feature of any regression analysis is the stability of its parameters across the given time regime to detect any structural change. The Chow test is commonly used to test for structural change in model parameters where the disturbance term is assumed to be the same in both periods.

Table 7: Chow Breakpoint Test

	Null Hypothesis	F-Statistic	Decision
Post GFC Model Comparison	The impact of major currencies on yuan is the same during regimes 2/1/1999-6/30/2009 and 7/1/2009-8/1/2018.	42.3493***	Rejected
Pre-BRI Model Comparison	The impact of major currencies on yuan is the same during regimes 2/1/1999-6/29/2012 and 7/2/2012-8/1/2018.	31.6946***	Rejected
Pre and BRI Model Comparison	The impact of major currencies on yuan is the same during regimes 7/2/2012-6/30/2015 and 7/2/2015-8/1/2018.	10.8357***	Rejected

*, ** and *** indicate the rejection of null hypothesis at 10 percent, 5 percent and 1 percent level of significance.

We run Chow-Breakpoint tests to examine the possibility of structural breaks in the parameters of the OLS models in Table 5. We run the analysis for the three cases. The first one is the post-GFC period where a structural break is introduced in the middle of 2009. The next one is the pre-BRI time period where a structural break is proposed in the middle of 2012. Our third case examines the data period three years prior to and three years following the announcement of the BRI; a structural break is proposed during the middle of 2015. In the first case the value of the F-statistic is significant, which leads us to reject the null hypothesis of the model's structural stability, and to conclude that the estimated parameters of the model are not same during the two sub-periods, i.e., 1999-2009 and 2009-2018. A similar result of structural instability holds for periods before mid-2012 and afterwards. Finally, the Chow Breakpoint tests highlight structural changes in the pre-BRI and the BRI periods.

5. Conclusion and Implications

Our study looks into how the yuan exchange rate has evolved over time vis-à-vis other hard currencies. Comparing the distributions, we observe that the yuan's daily returns are characterized by a relatively low standard deviation, but high kurtosis compared to the other hard currencies, which should be a tell-tale sign of a managed currency. The highest incidence of extreme returns is observed during the fixed exchange rate regime, but more recently the yuan's extreme movements seems to have been attenuated. The currency still exhibits comparatively

lower standard deviation and higher kurtosis. It seems that though the yuan's empirical distribution has moved closer to those of other international currencies, it remains distinct.

We examine the time-varying correlation of the Chinese yuan with other currencies by extracting Dynamic Conditional Correlation (DCC) series. We observe that there is a long-term trend of increasing correlations over the period. However, this long-term trend seems to be mostly driven by higher correlations in the Belt-and-Road-Initiative (BRI) period. We find that around 2015 there is a marked increase in the DCCs vis-a-vis the dollar. With respect to EUR and GBP, the DCCs increased steadily from around 0.20 to around 0.60-0.70in the post-GFC period. In case of the Japanese yen, the DCCs increased from around 0.10 to about 0.80 during the BRI period. However, the DCC's are still seen to be fluctuating within a wide range and appear to be rather unstable, and it remains to be seen if the higher levels of correlations would be sustained.

We also examine how the yuan exchange rate is being influenced by the other major currencies. During the full sample period, we observe that less than 13 percent of the variation in the CNY is explained by the four major trading currencies. In the recent sub-periods (pre-BRI and BRI) this explanatory power has increased to 73-82 percent, and, in addition to the US dollar, the euro, British pound and the Japanese yen are also exerting statistically significant influence on the Chinese currency. This indicates that yuan is increasingly being integrated into global foreign exchange markets, and the Chinese economy's influence on the other major economies is transmitted through the foreign exchange markets, particularly after 2015.

Our results point to the growing role of the renminbi and suggest that China's economic influence now comes increasingly through the foreign exchange market. It follows that global exports and overall growth will be affected by changes in the yuan's exchange rate by altering their relative competitiveness. Similarly, changes in China's monetary policy may lead to fluctuations in the economy's external demand. The continuing growth of the renminbi's influence in the global markets will depend on the progress in China's capital account liberalization and to the extent that convertibility of China's currency is achieved. The renminbi's influence will also increase as cross-border

trade settlements become more prevalent and channels of outward and inward flows widen, increasing both the supply and the demand for renminbi. Financial institutions may also be attracted by the growing depth of the renminbi market and shift their operations to this market, providing a further boost.

Since, the China-Pakistan Economic Corridor (CPEC) is a significant event in Chinese-Pakistani economic relations, the rise of yuan carries significant implications for the management of Pakistan's foreign currency reserves and exchange rate. With the IMF's decision to include the renminbi in the SDR basket, there is an expectation that the share of the yuan as a reserve currency held by the foreign central banks will necessarily increase. However, the IMF's decision does not in itself make the yuan an international reserve currency. As Wang (2015) notes, inclusion of a currency in a country's foreign exchange reserve portfolio by a government should depend on a number of factors such as the currency's convertibility, credibility and liquidity.

The peculiarities of the statistical distribution of the yuan noted by our analysis are likely to reflect the currency's convertibility, credibility and liquidity. With regard to each of these economic considerations there are certain concerns. First, there are indications that despite China's liberalization of its currency, many mechanisms of capital controls remain intact through licensing, quota allocation and other forms of intervention (Wildau, 2015).

Second, for the yuan to be an international reserve currency there will also have to be greater confidence in Chinese economic and political institutions such as an independent central bank and a competent judicial system. International investors and institutions would need assurance that their holding of renminbis not at risk from arbitrary actions of the government.

Thirdly, for a currency to be liquid in the international context, it has to be first widely held by international investors and institutions. For that to happen, the country has to have overall balance of payment deficits; on the contrary, China has run persistent current as well as capital account surpluses. To increase international yuan liquidity, China would need to lend, invest and provide aid denominated in renminbi. The Belt and Road

Initiative with its massive size will help to promote holding of renminbi abroad. However, China has also been trying to reduce its very large holdings of dollar-denominated assets, which has resulted in most of its outbound investment being in US dollars.

It is likely that, given the advantages of being an international reserve currency, the Chinese authorities would continue to implement financial reforms and the strategy of internationalizing the yuan. However, as there are disadvantages to it as well, the Chinese are likely to proceed with caution which means that it may take some time for the renminbi to become an international reserve currency. Given China's growing share of the global economy and the increasing internationalization of its currency, adding the renminbi to the Pakistan's reserve basket seems logical. It will contribute to a movement away from the current heavy reliance on the US dollar and will help minimize the fluctuations in the Pakistani rupee value against the major currencies.

As Liao and McDowell (2016) conclude, "the decision to invest in RMB is not simply an economic choice. It is also a political act that signals and symbolizes a state's preferences for a diminution of American global influence and support for a revised order." Considering the developing relationship between Pakistan and China, it seems that over time Pakistan will hold a larger portion of renminbi in its reserve portfolio. However, it would be prudent to base such decisions on economic considerations, particularly as Pakistan is still highly dependent on the inflow of US dollars and frequent recourse to IMF stabilization packages.

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Appendix

TableA1: Durbin Watson Statistic Value for Full Sample Period

	EUR	GBP	USD	YEN	CNY
Durbin-Watson Statistic	1.9838	1.9560	1.7057	2.0017	2.4270

The value of statistic reported in the cells tests the null hypothesis that there exists no serial correlation. Value closer to 2 considered in acceptable range.

TableA2: Summary Statistics of Residuals

	$Res_{t,(Euro/PKR)}$			
	Full Period	**Post GFC**	**Pre-BRI**	**BRI**
Skewness	0.1281	0.0705	-0.1642	0.3253
Kurtosis	4.8307	4.0839	4.6453	10.2241
Jarque-Bera	337***	39***	92***	1767***
	$Res_{t,(USD/PKR)}$			
Skewness	4.1269	-0.1993	-0.0697	5.9998
Kurtosis	90.5311	4.1775	9.2751	107.21
Jarque-Bera	1638474***	50***	1284***	369540***
	$Res_{t,(RMB/PKR)}$			
Skewness	-13.363	-0.2753	-0.1586	2.968
Kurtosis	573.339	8.2911	7.2944	47.6349
Jarque-Bera	69098814***	923***	604***	68090***
	$Res_{t,(GBP/PKR)}$			
Skewness	-0.2620	-0.1927	-0.1634	-0.5142
Kurtosis	7.6149	2.9719	4.8388	14.0477
Jarque-Bera	2132***	4.8708	113***	4134***
	$Res_{t,(YEN/PKR)}$			
Skewness	0.2368	-0.1329	-0.1551	0.5584
Kurtosis	7.734	6.1632	4.3104	11.094
Jarque-Bera	4797***	329***	59***	2242***

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A Policy Move towards Sustainable Urban Transport in Pakistan: Measuring the Social, Environmental and Economic Impacts of Lahore BRT System

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Abstract

We examine the impacts of a sustainable urban transport initiative in Lahore, Pakistan, the Bus Rapid Transit System (BRT), launched in 2013. We measure the socio-economic and environmental impacts of the BRT using a questionnaire-based survey that collected information on customers' travel purpose, travel frequency, travel time, mode access, previous travel mode choices (pre-BRT) and travel mode choices at present. We estimate that, on average, a BRT passenger saves about 46 minutes per day on a single trip. However, the modal shift from personal automobiles to the BRT system is found to be only 4 percent, i.e., significantly less than the shift found in other worldwide BRT systems. Moreover, we estimate the reduction in the number of private vehicles on roads, total distance travelled in km and associated travelling costs and, subsequently, the reduction in the carbon emissions. We conclude that the Lahore BRT transit system needs to be expanded to other parts of the city.

Keywords: Urban transport, Bus Rapid Transit System, travel time saving, vehicle costs saving, environmental emissions reduction, Lahore, Pakistan.

JEL Classifications: R49.

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1. Introduction

Sustainable urban transportation is at the core of sustainable urban living; it allows people to move easily and interact socially, and minimizes negative externalities on public health and environment both for present and future generations. Urban transportation can be categorized into formal and informal modes: formal transportation modes are typically those which are designed, planned and provided by the city government such as walking and biking lanes, taxis, buses, trucks and rail, while informal modes are administered by the private sector such as "paratransit", "low–cost transport" "third world transport" carriers including mini–vans, two or three-wheel rikshaws and chingchies (Cervero, 2000).Formal urban transport is much popular in Eastern Europe and East Asia (comprising 45 percent of total trips), whereas it is less popular in Sub Saharan Africa (comprising only 5 percent of the total trips) because of unsatisfactory passenger's mobility demands (Dorina & Dominic, 2015). Consequently, informal modes of transport serve as "gap fillers" in these places (Mohareb & Felix, 2017). Besides, many commuters use their own private vehicles and become vehicle dependent, even in developing countries (Ramadan, 2016); the number of registered vehicles has been increased to 1776 million vehicles in 2015 from 982 million in 2005, and is expected to rise up to a potential 2.6 billion vehicles by the year 2050 (WHO, 2015; Wright & Hook, 2007).

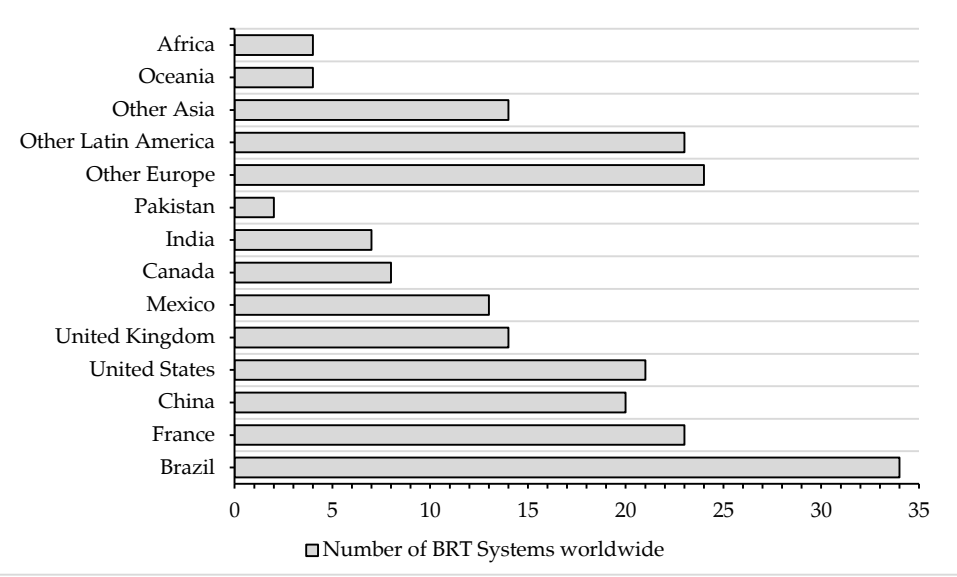
The rapid growth in motorization and vehicle dependency has created various problems such as traffic jams, travel uncertainty and delays, traffic accidents, increased energy (oil/gas) consumption, increased vehicle costs, urban air pollution and economic losses due to health issues and resultant foregone wages (Kogdenko, 2011; Greene & Wegener, 1997). Developing economies especially in Asia and Africa are searching for sustainable transport options (Haghshenas, Vaziri, & Gholamialam, 2013). According to Litman, (2017) public transit systems have the potential to resolve various traffic issues like traffic congestion, parking congestion, traffic accidents, road and parking infrastructure costs, automobile costs to consumers, inadequate mobility for non-drivers, excessive energy consumption and pollution emissions. Pojani & Stead (2015) have critically examined the nine commonly considered options for sustainable urban transport in cities, especially those in the

developing countries, and finds the Bus Rapid Transit (BRT) system is a viable policy option for large cities as it can serve approximately 45,000 passengers per hour per direction.

BRT operates on a separated right–of–way infrastructure that provides frequent, rapid operations in busy economies (Currie & Delbosc, 2014; Hensher & Golob, 2008; Wright & Hook, 2007; Yazici et al., 2013). Lautso et al., (2004) contends that BRT systems provide services that match the three legs of sustainability: social, economic and environmental sustainability. BRT systems help replace larger numbers of single occupancy vehicles (e.g., private cars and motorcycles) with a smaller number of higher occupancy vehicles such as buses and vans, which ultimately reduce vehicle costs and environmental pollution (Baghini et al., 2014). BRTs enhance urban quality of life in four ways:1) they reduce travel time, 2) diminish air pollution and greenhouse gas (GHG) emissions, 3) promote traffic safety and4) increase physical activity (Carrigan, et al., 2013). Safety benefits and increases in physical activity through walking are additional benefits of using BRT system (Carrigan, et al., 2013). BRT systems are ten times safer per kilometer than traveling by car according to one study (Litman, 2016). Further, BRT systems possess unique features as compared to the old transport systems like Intelligent Transportation System technologies that have increased operational efficiency and service quality. Although the BRT system is more cost effective than rail transit systems, it also requires large capital and construction investments in BRT infrastructure (Deng & Nelson, 2012; Hensher & Golob, 2008). However, mass transit systems are generally subsidized to promote social inclusion on account of social welfare benefits (Cropper & Bhattacharya, 2012; Serebrisk et al., 2009).

Around the world, people are moving from conventional transport systems to BRT. At present, 206 cities worldwide (including 42 Asian, 59 European, 67 Latin American, 29 North American, 4 African and 4 Oceanian cities) are serving more than 34 million passengers per day on 5,569 km routes through BRT systems (shown in Figure 1 below). Brazil is a leader in BRT, as 34out of the 67 cities in Latin America with BRT are located there.

Figure 1: Number of BRT systems worldwide.



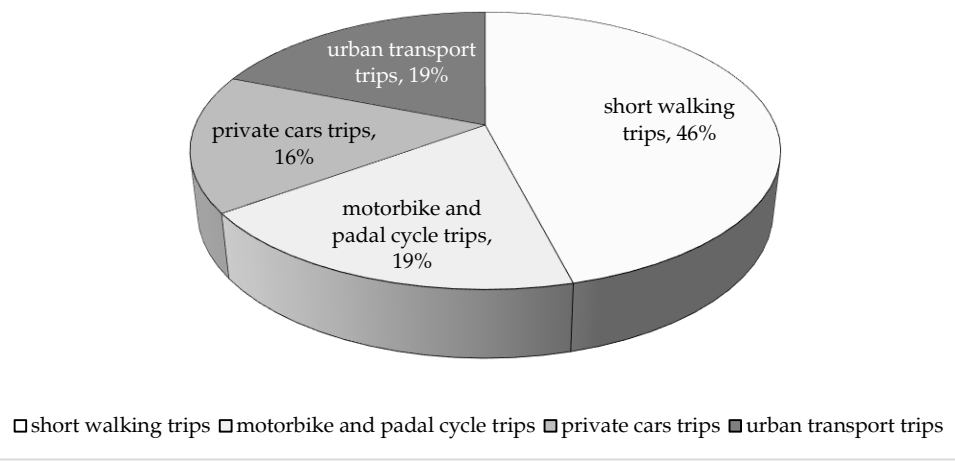
Source: *www.brtdata.org.*

BRT systems in Bogotá, Mexico City, Johannesburg, and Istanbul, have improved quality of life in four key areas: travel time saving, vehicle costs saving, reducing greenhouse gases (GHG) and local air pollutant emissions, and have led to improvements in traffic safety and higher physical activity (Carrigan, et al., 2013).

2. Urban Transport Problems and Lahore BRT System

Pakistan is the sixth most populous country in the world and after 2016 the urban population accounts for more than 40 percent of the total population. Lahore, the capital city of the Punjab province, is situated in the north eastern part of Pakistan and is the second largest city in the country with a population estimated at 9.54 million in 2015 (Bureau of Statistics, 2015) which makes it the 39th largest city world-wide (United Nations, 2014). The estimated transport demand in Lahore was about 17.7 million trips per day, which includes 8 million short walking journeys, 3.3 million trips by motorcycles or pedal cycles, 2.9 million trips by private car, and about 3.4 million trips by public transport during the year 2007 (ALMEC, 2012).

Figure 2: Estimated transport trips demand per day in Lahore.



Lahore's urban transport system currently comprises both formal and informal modes of transport such as Lahore Transport Companies (LTC) buses, mini vans, rickshaws, motorbikes, taxis and private cars. The current public transport services in Lahore are characterized by inappropriate operational timetables, inefficient use of road space and poor condition of public transport facilities (including bus terminals and buses) which combine to pose a severe challenge to urban connectivity. The factors responsible are escalated travel demand, inadequate capacity, improper governance, and poor urban transport planning (Dainichi, 2010; Imran, 2009). Like other developing economies, urban transport problems in Pakistan have been partially addressed by investing in roads and highways, while little attention has been paid to the provision public transport services at large (Kitamura & Jamilah, 2009). The implementation of these suboptimal transport policies and unfavorable public transport conditions has shifted passengers from high occupancy vehicles (buses and vans) to single occupancy vehicles (private cars). Consequently, the use of automobiles in Lahore has tripled over a decade i.e., 0.9 million in 2003 to nearly 4 million in 2014, significantly increasing urban congestion (Bureau of Statistics, 2015). In particular, this rapid increase in automobiles has triggered road congestion, fuel shortages, road traffic accidents and greater environmental pollution (Government of Pakistan, 2015-16). The transport sector has become the largest consumer of oil in the country (55 percent of total consumption), and oil import bills have reached up to $7.6 billion dollars (17 percent of the total

import bill) in 2016 (SBP Annual Report 2015-16). Accordingly, producing a given amount of economic output requires more than twice the amount of CO_2 emissions from transport as compared to regional averages. The economic loss to Pakistani road users and injuries is estimated to be more than Rs100 billion per year (Ahmed, 2007). Another important factor is the travel time unreliability (uncertainty about how long a trip will take, and unexpected delays) due to traffic congestion that becomes common during peak and rush hours, imposes additional costs to travelers and society. Ali et al. (2014) found that about PKR 1 million are lost daily due to traffic congestion in Karachi only.

Acknowledging these urban transport problems and the potential benefits of the BRT system realized globally, the Government of Punjab (Pakistan)established the Punjab Mass-transit Authority (PMA) with the aim to provide safe, efficient and comfortable urban transport in the major cities of Punjab. Lahore Metrobus System was its very first BRT system, initiated in February 2013. It is a 27 km-long route running in the North–South direction crossing at the center of Lahore connecting the Gajjumata and Shahdara bus terminals. Figure 3 shows the Lahore BRT corridor. Typically, a BRT system should be launched at such locations of the city where traffic volume is almost 2000 to 4000 passengers per hour per direction (Wright & Hook, 2007). In Lahore, the traffic volume is estimated to be between 7000-9000 per hour during off-peak to peak hours.

Lahore BRT has a maximum speed limit of 31 miles per hour, while its speed in commercial areas is limited to16 miles per hour. It offers daily service, running from 06:15-22:00 hours. The transit signal priority at the road intersections reduces delays at traffic lights. Like other BRT systems in the world, Lahore BRT operations are also administered via modern technologies that mainly focus on speeding up vehicle movements and passenger boarding by the application of measures such as Intelligent Transportation System (ITS), Passenger Information System (PIS), off-board ticketing and an Automated Fare Collection (AFC) System. According to the PMA estimates, daily

ridership is about 130,000 trips, which cover approximately 1.7 percent of overall motorized trips in the city in year 2015[1] (PMA 2015).

The utility of any public transport system is derived from its affordability, accessibility and the quality of services (Maunganidze, 2011). Wan et al. (2016) found that service frequency, speed, and on–time performance critically affect satisfaction level among riders across all routes, and service quality and accessibility play an important role in attracting new passengers to BRT systems. Modal shifts to BRT are also influenced by the traveler's demographic and socio-economic attributes, like gender and age, and trip–related attributes, such as trip purpose, travel time savings, trip costs, trip distances, and weekly travel frequencies (Wang Y. W., 2013). Hess (2009) suggests that the walking distance to public transit has a significant influence in predicting ridership frequency. According to Katrin (2017), each additional five minutes in perceived walking time to public transit decreases ridership frequency by 5 percent for non–drivers and by 25 percent for drivers in San José, California (USA). This implies that policy makers should not only focus on provisioning the transit systems, but also focus on understanding the determinants of the mode choice access and essential service parameters to be considered to achieve success.

Currently, the BRT system is running in 3 major cities of Pakistan namely, Lahore, Islamabad, and Multan. The Government of Pakistan is considering the expansion of existing BRT networks and the introduction of transit systems in additional cities. It is therefore important to evaluate whether the Lahore BRT has provided social, environmental and economic benefits.

[1]Since 2015, ridership of Lahore BRT has continued to rise, now reaching up to 179,000 riders per day, and about 250 million passengers have travelled by Lahore BRT since its inception in year 2013 (as reported by PMA website).

Figure 3: Lahore BRT corridor

Our study attempted to answer the following questions:

Q1: Does Lahore BRT save travel time?

Q2: Does Lahore BRT reduce the vehicle miles travelled?

Q3: Does Lahore BRT attract passengers away from personal car use to Lahore BRT?

Q4: Does Lahore BRT reduce environmental emissions?

Q5: Does Lahore BRT promote social integration?

Q6: Does Lahore BRT help boost physical activity among passengers?

We addresses these questions and evaluate the performance of the Lahore BRT system on the basis of the established parameters discussed in the literature (Wan, 2016; Wang Y. W., 2013; Hess, 2009; Katrín, 2017; Maunganidze L. , 2011). To the best of our knowledge, only Mansoor et al.(2016) have analyzed the Lahore BRT up to now; these authors have gathered public opinions and discussed the positive impacts of the Lahore BRT in pre- and post-implementation periods. However, they did not attempt to quantify the socio-economic and environmental impacts such as travel time savings, vehicle costs savings, reductions in vehicle distance traveled and reductions in environmental emissions.

3. Data and Research Methodology

Wright and Hook (2007) suggested that the customer's opinion is perhaps the single most important variable that measures the utility of public transport projects. A significant amount of research has evaluated public transit systems based on both passenger perceptions and transit agency performance indicators (Eboli & Mazzulla, 2011; dell'Olio, 2010; Shreya & Debapratim, 2013).

Our study is based upon questionnaire-based survey information that was collected in 2015 from passengers who have travelled on the Lahore BRT. We used the methodology developed by Cochran (1963) to determine a representative sample size for the desired level of precision, desired confidence level and the accurately represented attributes of the target population. Our analysis found that a sample of 385 respondents was sufficient to study the target population of about 13,000 riders. In the present study, we have surveyed a total 760 passengers i.e. larger than the required as per this criterion, so we are confident that our sample size is large enough to study the attributes of the target population.

Using primary data, we identify Lahore BRT passengers' transport patterns and estimate total time saving, vehicle cost saving, environmental emission reduction and associated socio-economic benefits. Furthermore, we outline recommendations for the improvement and better utilization of the Lahore BRT system.

3.1 Survey Design

Our study adopts the questionnaire from the studies of Dickey (2008) andDeng & Nelson (2012). We distributed 850 questionnaires in total out of which 760 were usable for our analysis. Since travel behavior of passengers fluctuates between weekdays and weekends, responses have been collected on three weekdays (20th, 23rd and 24th February 2015) and two weekend days (21st and 22nd February 2015) at different times(Pas & Sundar, 1994; Kitamura & T, 1987; Hanson & Huff, 1982; Hanson & Huff, 1986; Huff & Hanson, 1990; Aguiléra, Massot, & Proulh, 2009).The survey was conducted during the morning rush, noontime, afternoon and evening times to minimize potential biases created by sampling time. Also, there were no significant public events (such as national or

provincial sports festivals) during our sample time period, which could have impacted the validity of our sample (Deng & Nelson, 2012).

The travelers were randomly selected during their journey and requested to fill the questionnaires. The survey had a high response rate (89.4 percent). Almost 60 percent of the questionnaires were filled by the travelers themselves while the remaining 40 percent were completed through interviews at entry and exit points of the Lahore BRT stations.

3.2 Methodology

The survey responses on passengers' demographic and socio-economic (gender, age, income, occupation) factors, trip related attributes such as trip purpose, trip frequency, trip cost, mode choices in the past (before the introduction of Lahore BRT) and mode choices at present, travel time savings and accessibility features were used to evaluate the Lahore BRT performance. Other BRT social impacts such as improved physical activity, reduction in travel time, reduction in road congestion, and reduction in vehicle miles traveled were also estimated. Estimated reductions in vehicle miles traveled were utilized to calculate the reduction in environmental emissions and vehicle costs saving.

According to the US Environmental Protection Agency, CO_2 emissions of a typical passenger vehicle from a gallon of gasoline are 8,887 g and CO_2 emissions from a gallon of diesel are 10,180 g (EPA, 2014). The emission of carbon dioxide contents from an average passenger vehicle per mile is calculated from the amount of CO_2 emitted after burning one gallon of fuel and the average mileage i.e., miles per gallon (MPG) as defined by:

$$CO_2 \text{ emissions per mile} = \frac{CO_2 \text{ per gallon}}{MPG} \quad (1)$$

In this way, CO_2emissions per mile are estimated to be 411 g per mile, based on 21 miles per gallon estimates. Next, total annual CO_2 reduction can be calculated by multiplying it with the estimated reduction miles per year:

$$\text{Annual } CO_2 \text{ emissions reduction} = \frac{CO_2 \text{ per gallon}}{MPG} \times \text{miles reduced per year} \quad (2)$$

We follow Litman's (2015) methodology to measure the economic value of travel time saving, vehicle cost savings, and pollution cost savings. Economic value of travel time savings is calculated by multiplying the number of hours saved with 35 percent of the average hourly wage rate in Pakistan. The economic value of vehicle cost saving is calculated by multiplying the number of reduced vehicle miles traveled with the value of estimated vehicle cost per mile (i.e., $0.35 per mile). Similarly, the economic value of pollution costs saving is calculated by multiplying the number of reduced vehicle miles traveled with the cost of pollution saved per mile (i.e. $0.05 per mile).

4. Survey Outcomes and Discussion

4.1 Demographic Profile and Service Utilization Characteristics of Lahore BRT Users

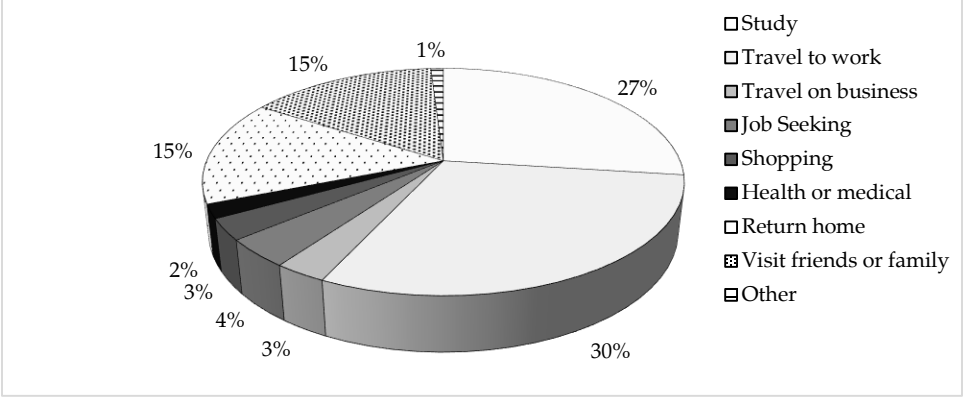
Lahore BRT users are classified by gender, age, education, income level and occupation as shown in Appendix A. Among the survey respondents, 80 percent were male, and the majority were young, aged 18 to 34 years. The majority of the respondents possess at most a metric degree (10 years of education) and belonged to lower income groups. The BRT costs PKR 20 per trip irrespective of distance covered, i.e. comparatively cheaper than other modes of transport in the city. According to the survey results, more than 50 percent of the respondents utilize Lahore BRT more than once a day while 14 percent of them use this service 4 to 6 times in a week and 11 percent of the respondents use this service 1 to 3 times per month. A majority of the respondents had been utilizing this service for some time, implying that it has become a regular transport mode for their return trips and that they are generally satisfied with its services (see in Appendix A.) Seda et al. (2017) find that access mode variables are more important than total travel time for traveler's satisfaction, confirming the significant role of access in multi-modal travels. The majority of respondents (47 percent of the total) access Lahore BRT stations by walking, while 24 percent use vans to get to the stations.

4.2 Travel Purpose and Social Integration

Generally, people prefer to use their own private cars or rented cars to visit family and friends (Adeel, Yeh, & Zhang, 2016). In the case of

the Lahore BRT, more than 50 percent of passengers use the service for traveling to study and work, whereas 15 percent are traveling in order to visit friends or family (Figure 3). This implies that the Lahore BRT is not only providing commuting services for economic activities but also supporting social activities among the people living along the corridor.

Figure 4: Main purpose of Lahore BRT trip.



4.3 Improved Physical Activity

Mass transit systems are playing a vital role in improving physical activities, as passengers need to also walk to complete their journey (Chad et al., 2017). Survey results show that 47 percent of the respondents get access to Lahore BRT stations by foot (as shown in Figure 5), and similarly 48 percent of the total travelers complete their journey by walking to their final destination (Figure 6). In this way, the Lahore BRT also promotes physical activity among the passengers.

Figure 5: Transport mode used to get final destination.

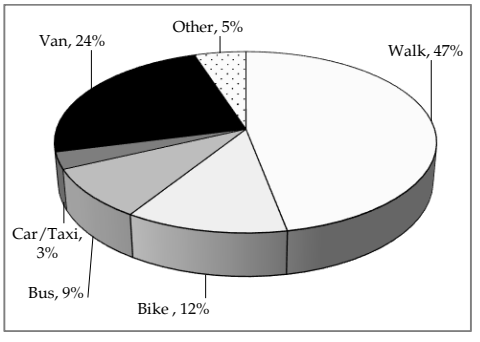
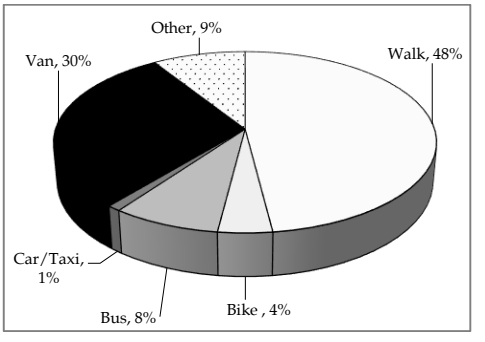


Figure 6: Transport mode used to reach on final access to the Metrobus station



4.4 Reduction in Travel Time

Travel time saving is typically the primary benefit of any transport project. According to the General Manager Operations of Punjab Metrobus Authority, the time it takes to travel16.8 miles from the Gajjumata station to the Shahdra station was reduced from one hour and 40 minutes before the inception of Lahore BRT to 55 minutes after its inception (PAKSTRAN). Our survey responses show that the majority of respondents complete their Lahore BRT journey within 12-36 minutes (Figure 8). The commercial speed of Lahore BRT is 16.2 miles per hour (PMA), and the average distance traveled by each passenger in a day is 6.5miles per trip, or 13 miles in a day if a typical passenger returns by the same mode of transport.

Figure 7: Total time of Lahore BRT trip

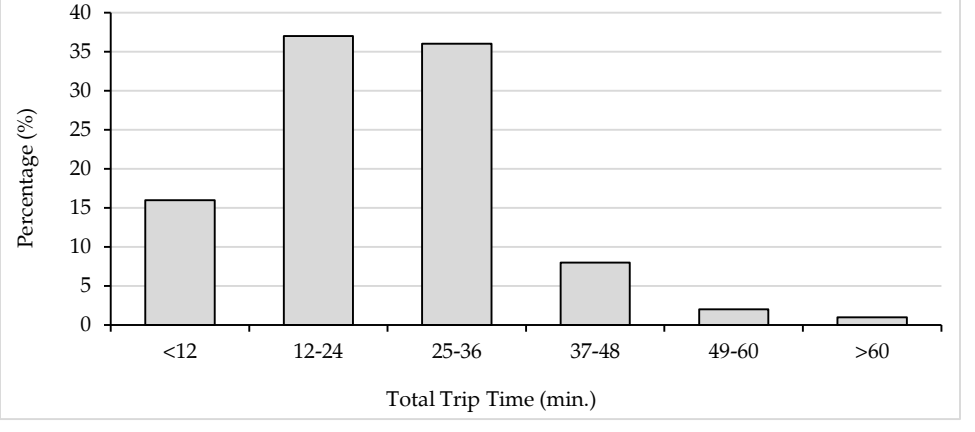
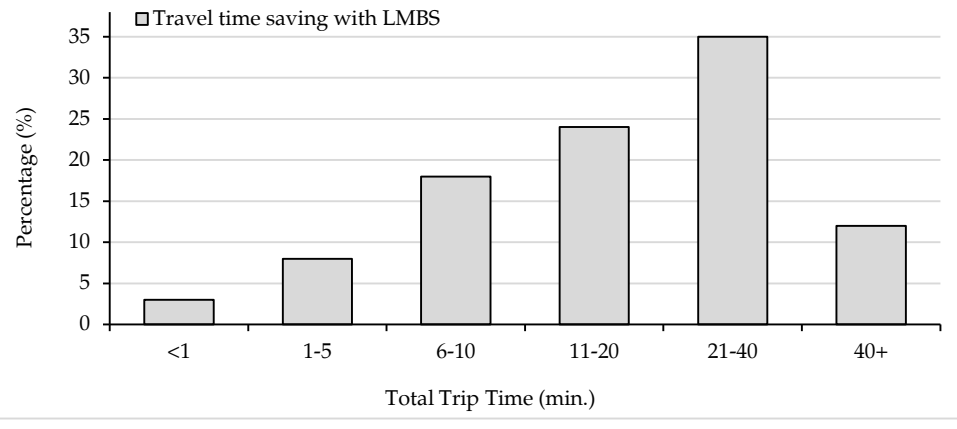


Figure 9 shows that about 35 percent of the respondents save about 21-40 minutes per trip by riding on MBS, and 24 percent of the respondents save about 11-20 minutes per trip, while the remainder save less than 10 minutes per trip. So, on average a passenger saves about 23 minutes per trip or 46 minutes per day if using the same service again when returning home.

Figure 8: Travel time saving with the Lahore BRT



Aggregating our results, we estimate that each passenger who used the service twice a day saved about 12 days of travel time in2015. Extrapolating to all passengers (approximately 130,000) of Lahore's BRT, a total of about 18 million hours have been saved in the year 2015 (Table 1). This saved travel time has the potential to be utilized for other social and economic activities.

Table 1: Travel time savings and value calculations.

(1)	(2)	(3)	(4)	(5)	(6)
Avg. time saving per commuter per trip	Total time saved per day (hours)	Time saved (days per commuter per annum	Total time saved (hours) per year by all commuters	Value of total time saved per year (USD)	Value of total time saved per year (PKR*)
23 Minutes	49,833 hrs	12days	18,046,491	$ 7.77 million	814.19million

*Exchange rate: PKR 104.8 per USD in 2015.

Source: Author Calculations (based on travel time saving estimates)

The average monthly wage rate is US$ 255 in Pakistan (Statista, 2012). There are 26 working days in a month translating into an average wage rate of $1.23 per hour. The value of total travel time saved is worked out by multiplying the number of total hours saved (travel time) with 0.35 of the hourly wage rate. In this way, the value of travel time saving is estimated to be US$ 7.77 million and PKR 814.19 million rupees for the surveyed year 2015 (Table 1).

4.5 Modal Shift to Lahore BRT

Globally the modal shift from autos to BRT ranges generally between 9 and 40 percent (Figure 9), and several factors are responsible this shift such as cost of riding, safety, availability of alternatives, travel obstacles along with footpaths, reliability, frequency, cleanliness, comfort, crowding, information, ticketing, safety, security, speed, fare, accessibility and staff courtesy (Wan, 2016; Hess, 2009).

The observed modal shift from personal autos to Lahore BRT is only 4 percent (Figure 10). However, the literature has found that even a fractional mode shift towards the use of public transport or non-motorized transport from motorized ones would have immense impacts in terms of environmental emission reduction (Wright & Fulton, 2005).

Figure 9: Worldwide Modal shift from Auto to BRT System *(Wang Y. W., 2013)*.

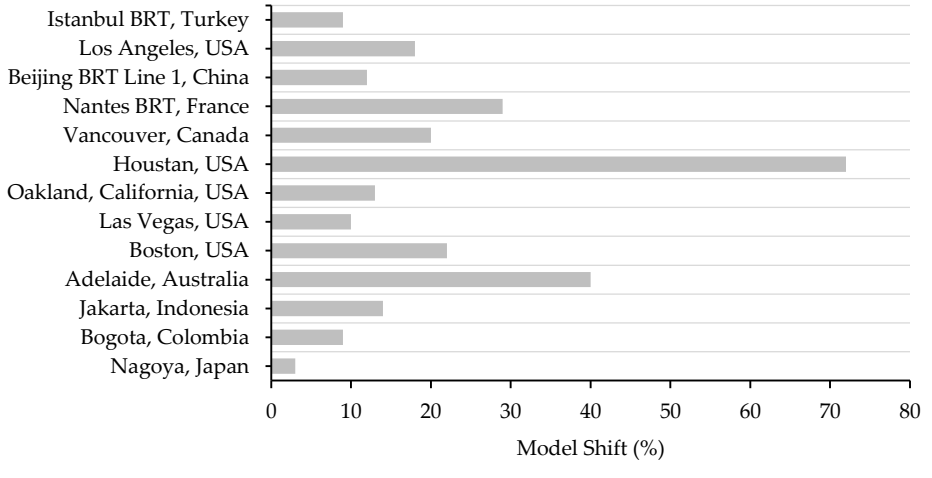
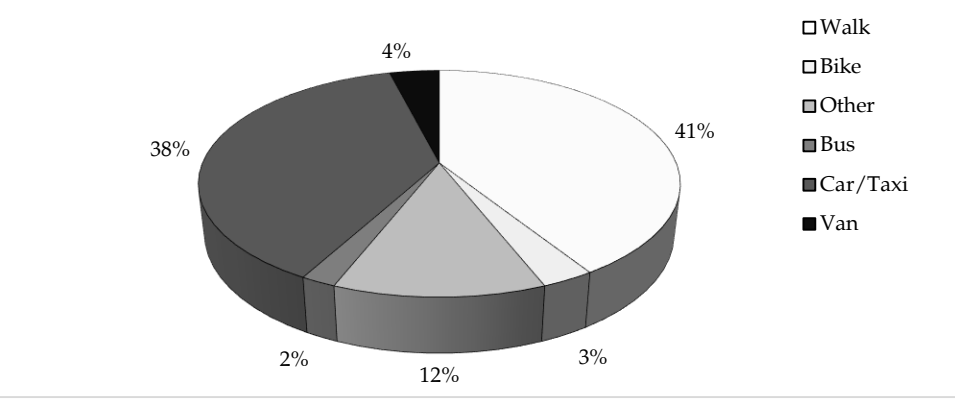


Figure 10: Travel Modal shift to Lahore BRT.



4.6 Reduction in Private Vehicles and Road Congestion

We estimate reductions in private vehicles and private vehicle costs based on the observed modal shift and passengers' car ownership (see Table 2). According to the survey results, 4 percent passengers have shifted from personal autos to Lahore BRT Figure 11). Ridership is about 130,000 per day, so we estimate a reduction of about 5,200 automobiles per day on the roads due to Lahore BRT operations. A single passenger of Lahore BRT travels on average 10.4 km per trip daily and there is a reduction of approximately 33.6 thousand vehicle miles per day by Lahore BRT passengers.

But according to our data, 16 percent of passengers have the "alternative mean to travel for this trip i.e., their own personal car" (see Table 1, Appendix A), but prefer to travel by Lahore BRT. Under this alternate scenario, we estimate a reduction of approximately 20,800 autos per day on the road sand about 134.4 thousand vehicle miles per day (Table 2). The Lahore BRT services can potentially save these passengers from traffic jams and road accidents. Further, when automobile clients shift to the transit system, they save fuel costs, maintenance costs, parking and insurance costs, and ownership costs as suggested in Litman (2015). These vehicle costs in total are almost $0.30 dollar per mile at off–peak and $0.40 dollar per mile at urban peak times. This average rate ($0.35 dollar) is multiplied with the estimated reduction in vehicle miles traveled in order to calculate the

economic value of vehicle costs saving for passengers who opted for the Lahore BRT.

Our original estimates show that each passenger of the Lahore BRT has saved about $33 per year amounting to a total of $4.3 million per year for all passengers of Lahore BRT (based on observed 4 percent modal shift in survey results). If instead we assume the alternate scenario based on the 16 percent of riders who own a car, passengers have saved about $17.2 million dollars per year (calculations are shown in Table 2).

4.7 Reduction in Environmental Emissions

The rapid increase in vehicles, excessive consumption of fuel, smoke clouds and dust are negatively impacting the natural aesthetics as well as the environment of cities and having serious health impacts. According to the WHO assessment, about 92 percent of the world population lives in the areas where the minimum WHO environmental standards are not met. Motorized vehicles are the largest contributor (59 percent) in anthropogenic CO_2 emissions worldwide, particularly in urban areas. In Pakistan, the transport sector is the largest consumer (i.e. 55 percent) of petrol and petroleum products and is therefore the largest contributor of related carbon emissions(Government of Pakistan, 2016).In the case of Lahore, the road transport sector produces 92.8 percent of total transport related CO_2 emissions(EGC, 1998; Zaman, 1999).

Table 2: Estimated vehicle miles reduction and costs saving.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Scenarios	No. of vehicles reduced per day	Average Distance travelled (per trip)	Average reduction in vehicle miles travelled (per day)	Average vehicle costs saving (per day).	Annual vehicle costs saving* (USD)	Annual vehicle costs saving** (PKR Rupees)
Mode shift (4%)	5,200 autos	10.4 km	33604	$ 11,761.3	$4.3 million	PKR 0.5 billion
Car Alternative (16%)	20,800 autos	10.4 km	134,415	$47,045.3	$17.17 million	PKR 1.8 billion

*Vehicle cost saving in dollars is $0.35 per mile as suggested in Litman (2015);

** Vehicle cost savings in PKR is calculated using an exchange rate of PKR104.8 rupees per 1 USD in 2015.

Source: Author Calculations (based on average trip distance travelled by passengers).

BRT systems worldwide have reduced greenhouse gas emissions (Baghini et al., 2014; Carrigan, et al., 2013). We estimate a total reduction in CO_2 emissions of about 14 tonnes per day and 5.041 thousand tonnes per annum based on the 4 percent modal shift we observe for the Lahore BRT system. However, if we assume that there is the reduction of about 20,800 car trips (based on the 16 percent of passengers who own a car), then we estimate a reduction of about 55 tonnes CO_2 reduction per day and 20.2 thousand tonnes CO_2 reduction per annum in Lahore (see Table 3).

Table 3: Reduction in environmental emissions.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Scenarios	No. of cars reduced per day	Average distance travelled (per trip)	Average reduction in vehicle miles travelled (per day)	Average environmental emissions reduction per day.	Annual reduction in Pollution costs™ (USD)	Annual reduction in Pollution costs (PKR Rupees)*
Mode shift (4%)	5200	10.4 km	33,604 miles	14 tonnes	$ 0.61 million	Rs. 64.27 million
Car Alternative (16%)	20800	10.4 km	134,415 miles	55 tonnes	$2.45 million	Rs. 257.08 million

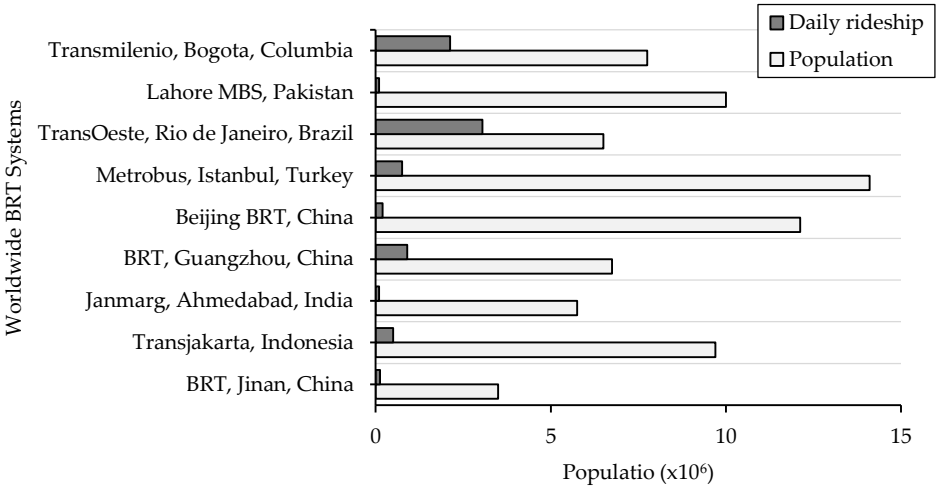
™Average car pollution costs is about $0.05 per mile (Litman, 2015)
*Environmental emission reduction in Pak Rupees is calculated by multiplying the exchange rate i.e. 104.8 rupees per dollar in year 2015 (exchange rate).
Source: Author calculations.

The annual reduction in pollution costs is about US$0.61 million and US$2.45 million under the modal shift (i.e. 4 percent of passengers) and the car ownership (Column 6 of Table 3) scenarios (16 percent of passengers) respectively. Our study reveals that reductions in CO_2 are less evident because of limited modal shift from private car owners to BRT. The existing network of Lahore BRT is currently only catering to the travel demand of 1.3 percent out of a population of almost 10 million. This points to a need to expand this transit system on other routes of Lahore as well.

Although the overall impact of Lahore BRT is positive, this system has not yet attracted a significant ridership from the among the more educated or higher income groups. Potential barriers may include various

demand and spatial related constraints as identified by Adeel et al.(2016),as passengers might find it an imperfect substitute for their own private cars, because of inadequate access and insufficient parking at Lahore BRT stations.

Figure 11: Ridership comparison with other worldwide BRT systems.



5. Conclusions and Policy Implications

Rapid urbanization, urban sprawl and motorization have generated a wide range of transport problems in many large cities in Pakistan. To resolve this, the Government of Pakistan started its first BRT system in Lahore in 2013. This paper attempts to evaluate this project in terms of social, environmental and economic impacts. We have undertaken a survey and our results show that at present most of the users of the Lahore BRT are students and workers belonging to low income categories. In addition, the Lahore BRT can play a role in promoting social welfare as 15 percent of total commuters use this service exclusively for visits to friends and family. Also, since many respondents arrived at Lahore BRT stations daily on foot, the system may help passengers increase physical activity.

Other considerable positive impacts of this BRT system are related to service efficiency in terms of travel time saving, vehicle cost savings and reductions in environmental emissions. We estimated that on average each passenger has saved 23 minutes in a single trip and 46 minutes in an average day. The total economic value of this travel time saving for the entire ridership is approximately US$7.77 million per year. According to the modal shift statistics (i.e., 4 percent of passengers), the

Lahore BRT reduces vehicle miles traveled by about 12.2 million per year and has resulted in vehicle costs saving of about US$4.3 million per year. The annual reduction in CO_2 emissions is about 5 thousand tones reducing pollution costs by about US$0.33 million per year.

Our results also found that 16 percent of the total respondents have alternative transport i.e., personal vehicles, but prefer the Lahore BRT, mainly because it is less expensive, more convenient and they wish to avoid traffic. Travelling by the Lahore BRT has reduced the number of vehicles on the road by about 20,800 vehicles leading to a reduction in vehicle miles of about 134.14 thousand vehicle miles. In this case, reductions in CO_2 emissions are estimated to be 55 tonnes of CO_2 per day, saved vehicle costs are about US$17.17 million and reduced pollution costs are about $2.45 million dollars per year via this transit system. But it is important to note that the Lahore BRT has not succeeded in a significant shift in the modes of transit. The main reason found in our survey was the attitude of private vehicle owners who are less likely to travel by the Lahore BRT transit system because of less comfort, absence of convenient Lahore BRT stations, lack of parking facilities near the stations, short and limited Lahore BRT routes in the city, and the capacity constraints of the system. Therefore, our results suggest expanding and upgrading this transit system to the entire city, building more parking places and developing the surrounding areas with pedestrian tracks near the MBS stations in order to attract more car owners to Lahore's BRT system.

Limitations

This study has focused on measuring benefits of Lahore's BRT, specifically travel time savings, number of vehicles reduced, vehicle costs savings and environmental emission reduction per year, while we have ignored the costs altogether. For example, time lost during the BRT construction phase and jobs lost due to suspended operations of other urban transport on the BRT route have not been taken into account. Further, our study has only covered the modal shift from personal cars to the Lahore BRT in measuring the benefits and ignored the modal shift from other vehicles like buses and vans. Likewise, environmental emissions reductions are calculated using US EPA standards because of the non-availability of reliable estimates in the case of Pakistan. Future studies may improve along these directions.

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Appendix

Appendix A: Summary of socio-demographic facts, travel choices and travel patterns of Lahore BRT users.

Socio-demographic Indicators	Categories	Percentage Share
Gender	Male	80
	Female	20
	Less than 18	18
Age	18 - 34	61
	35 - 49	15
	50 - 65	5
	Over 65	1
Education	Matric or below	29
	Intermediate	27
	Graduate	25
	Master	12
	MS/M.Phil.	3
	Ph.D.	1
	Other	3
Occupation	Civil servant	5
	Scientific Worker/Teacher	4
	Private company staff	13
	Self employed	5
	Student	44
	Worker	18
	Farmer	0.5
	Retired	1.5
	Unemployed	9
Monthly Income:	No income	50
	Less than 15,000	19
	15,001 – 30,000	24
	30,001 – 50,000	4
	Above 50,000	3
Having car alternative for this trip	Yes	16
	No	84
Travel Frequency	More than once a day	53
	1 time/day	0.5
	4 – 6 times/week	13.5
	1 – 3 times/week	11
	1 – 3 times/month	11
	Very seldom	11
Service Utilization since (Period)	Less than 1 month	4.1
	1 to 3 months	9.5
	3 to 6 months	18.9
	6 to 9 months	22.9

Socio-demographic Indicators	Categories	Percentage Share
	9 months to 1 year	9.2
	More than 1 year	35.4
Choice preferences	Avoid traffic	23
	Less expensive	14
	More convenient	19
	Avoid traffic + Less expensive	2
	Avoid traffic + More convenient	2
	Avoid traffic + Less expensive + More convenient	21
	Less expensive + More convenient	6
	other	13

Source: Survey Results

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Energy Consumption and Greening: Strategic Directions for Pakistan

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Abstract

We compare Pakistan's energy consumption structures to selected East Asian economies with a view towards ensuring an adequate supply of power for economic catch-up and, at the same time, meeting the greening goals envisioned by the United Nations Framework Convention for Climate Change. The evidence shows that Pakistan relies significantly less on non-renewable energy to meet its energy demands compared to China, Japan, South Korea, Malaysia, and Thailand, while itsdependence on fossil fuels has been rising rapidly.Usingdata for Pakistan from 1960 to 2015, we deployed panel co-integration and Granger causality teststo analyzeselected East and Southeast Asian countries before exploring what it will takefor Pakistan to develop its renewable energy(RE) sector. The evidence shows that catching up economically with these countries through rapid GDP per capita growth will exacerbate Pakistan's current energy imbalance, thereby aggravating greenhouse gas (GHG) and carbon dioxide (CO_2) emissions. We argue that Pakistan enjoys strong endowments to avert this problem, and hence, it should strategically focus on the development of RE resources, especially solar and wind energy, but only aftter taking account the relevant costs.

Keywords: Renewable energy, thermal energy, economic growth, hazardous emissions, Pakistan.

JEL classification: Q41, Q49.

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1. Introduction[1]

Energy is a critical resource in production, distribution, and consumption. Untilthe early 1970s,it was sought with little recognition for conservation and the environment, which is why early examples of deforestation and environmental degradation largely occurred in Western Europe, the United States, and Japan. Efforts to lower energy use was initially driven by sharply rising oil prices in 1973-75 and 1979-80.[2] Consequently, oil usage intensity among the International Energy Agency (IEA) countries fell considerably over the period 1973-1980 (Birol and Keppler, 2000). Meanwhile, energy use in the consumption of the Organization for Economic Cooperation and Development (OECD) countries fell by around a third between 1973 and 1998, which was a result of technical change that drove cost-saving innovations (Goldemberg &Prado, 2011; Nordhaus, 2019; González-Álvarez et al.,2020). Additionally, net oil importers, such as most Western industrial European countries (e.g., France, Germany, Italy, Spain), along withJapan, Korea, and Taiwan also attempted to reduce their dependence on oil and gas.

The second major push to stimulate a reduction in the use of fossil fuels was driven by concerns over climate change and global warming. Since the beginning of the twentieth-century, global atmospheric temperatures has risen dramatically following a rise in greenhouse gas emissions (GHG) (Stern, 2006; Nordhaus, 2019), which has spurred governmental and multilateral initiatives to mitigate climate change. As countries became aware of the dangers of climate change and global warming since the launching of the annual Conference of Parties (COP) of the United Nations Framework Convention for Climate Change (UNFCCC), participating nations agreed to reduce GHG emissions over the period 2008-2012 to 1990 levels (UN, 1997). Subsequently, in 2015, almost all of the UN members pledged to contribute towards capping temperature rise to 1.5 degrees Celsius over a century from 2005 levels (Rasiah et al., 2016;Rasiah et al., 2018;Alsaleh and Abdul-Rahim, 2019; Hussain et al., 2020; Mubarik and Naghavi, 2020), although the United States withdrew from that pledge in 2017. Unlike previous efforts, the

[1]We wish to thank the two anonymous referees for their constructive comments. The usual disclaimer applies.

[2] Oil prices rose sharply in 1973-75, and in 1979-80 (Sachs, 1982).

COP meetings aim to mitigate climate change and global warming without compromising economic growth following the work of Stern (2006) and Nordhaus (2019). Carbon taxes and the development of renewable backstop technologies to substitute for fossil fuels and reduce the energy intensity of output, and inducements to promote sustainability transitions have been the prime channels through which these countries have targeted their energy transition roadmap (Birol &Keppler, 2000; Nordhaus, 2019; Baležentis et al., 2011;Adom &Kwakwa, 2014; Kwakwa et al., 2020).

Natural resources offer Pakistan substantial endowments to shift towards renewable energy(RE), including biodegradable crop straws to replace nitrogen and phosperos fertilizer (Zhuong et al., 2020). However, many of these resources have yet to be locally developed(Mubarik, 2015; Zafar et al., 2019). Hence, in 2015 most of the RE produced in Pakistan came from hydropower, accounting for 31 percentof electricity produced (Kamran, 2018). Wind, solar, and biomass resources have scarcelybeen developed, while oil, gas, and coal have remained the prime sources of fuels used in the country, which is not very different from the East Asian countries of China, Japan, South Korea, Malaysia, and Thailand. Thus, we have two objectives in this paper: First, we seek to examine energy sources trends and emissions of Pakistan in comparison with East Asian economies, and what likely consequences could face Pakistan if it managed to accelerate economic growth to catch up with the East Asian economies. Second, we attempt to test the relationship between GDP and RE on the emission of pollutants using greenhouse gas (GHG) and carbon dioxide (CO_2) emissions as the proxies. Its purpose is to see if drastic measures must be taken to develop green energy to reduce its dependence on non-renewable energy. Instead of comparing Pakistan with conventional peers like India and Bangladesh, we compare the country with the Asia-pacific countries because the energy generation and consumption of the Asia-pacific countries was similar to Pakistan before 2000 whenthe majority of these countries remaineddependent on fossil fuel for energy production (Shi, 2016). However, since 2000,the Asia-Pacific countries have significantly shifted towards the use of renewable resources in their energy mix which has grown by 2.5 percentannually (APEC, 2016).

Furthermore, Malaysia's total installed capacity is expected to reach 6235 GW by 2040 with renewable energy's share accounting for 35 percentof energy consumption. Malaysia has become a leader, producing 256,830 KTOE energy from renewable energy resources like solar, wind etc. (Hosseini and Wahid, 2014; IEA 2020). According to Hosseini and Wahid (2014), "*the available RSE resources such as biomass, biogas, solar, and mini-hydro for energy generation contributed around 5% of the country's total electricity demand.*"Pakistan's similarity with these countries in their earlier years, in term of the energy generation, and their successful change in energy mix offer a strong case to compare Pakistan with these countries. We also attempt to assess Pakistan's capacity to follow the footsteps of these nations to shift its energy mix with a significant expansion in the use of renewable energy resources. We excluded Singapore as the country is an outlier as the country that uses over 85 percentof its energy from natural gas with renewable energy only contributing 0.7 percentof energy consumption in 2015 (Energy Market Authority, 2020).

2. Theoretical Considerations

Hydroelectric power and coal were the significant sources of energy countries harnessed until the advent of oil and gas. Concerns overdependence on non-renewable sources of energy (i.e., fossil fuels) were initially because of theirscarcity, but subsequently those concerns have been largely over the harm they were causing to the environment.

The overcrowding of planet Earth through rapid population growth has been viewed as a demand-side problem facing the environment. Hence, the limits to growth argument advanced by the club of Rome resonated strongly among economists until the 1980s (Malthus, 1798; Ehrlich, 1968).

Using computer-simulated data Meadows et al. (1972) had argued that there are limits to economic growth, which did not resonate well with the governments of developing economies as it was viewed as an attempt to keep them underdeveloped. Theyquestionedwhy developing countries should carry the burden of the global common when the developed countries had themselves grown through environmental destruction. This argument was then superseded by the inverted "U"

shaped relationship between pollution intensity and economic growth, which was adapted from the original work of Kuznets (1955) that identified a similar relationship between income distribution and the logarithm of per capita GDP using a longitudinal study of the developed countries. Grossman and Krueger (1991) and Panayotou (1994) advanced the Kuznets inverted "U" shaped relationship between pollution intensity and GDP per capita, which assumed that all countries would experience a rise first and subsequently a fall in pollution intensity once a threshold of per capita income is reached so that the utility of the environment will exceed that of the utility of material development. Uddin (2014,p.60) also discussed how "in the early stages of economic growth, environmental quality decreases with an increase in per capita income, but after a certain level environmental degradation starts decreasing with the increase in the level of per capita income, thus resulting in an inverted U-shaped curve (i.e., Environmental Kuznets Curve, EKC). While the assumptions used by this argument are static, its biggest shortcoming arises from the fact that the environment is a global common so that it is inevitable that the consequences of climate damage in one location will have disastrous consequences on the whole globe. But despite this shortcoming, the EKC provides the theoretical basis to model the relationship of GDP with environmental degradation, which is represented by greenhouse gases and carbon emissions.

Since the turn of the millennium, following new scientific insights economists became convinced that climate change and global warming were human-made problems (Stern, 2006; Nordhaus, 2019; Rasiah et al., 2018), which facilitated the deployment of computable general equilibrium models in climate projections to cap changes in temperature. Consequently, efforts to cap temperature rise through the United Nations Framework Convention for Climate Change (UNFCCC) gained currency as countries sought to substitute non-renewable sources of energy with renewable sources. The Paris Accord of 2015 provided its landmark agreement as over one hundred countries pledged to cap temperature rise to 1.5 degrees Celsius over the next hundred years.

Given the role played by energy in economic development, and the mixed experience of economies – both resource-rich and resource-poor – in stimulating rapid economic growth and structural change, we

review the above theories in light of empirical evidence from East Asia and Pakistan. In addition, unlike the advocates calling for limiting economic growth, it is pertinent to look at Stern (2006) and Nordhaus (2019) ahd their call to focus on shifting energy sources from fossil to non-fossil fuels through the introduction of a carbon-intensive tax, which should then be targeted at the development of the backstop technologies that will quicken this transition.

While the short-run consequences of imposing a carbon tax can be destabilizing to the economy, its long-term consequences may not only ensure the greening of the earth but also create a sustainable domestic source of energy supply. The large-scale development of green energy sources – *e.g., wind, solar, and biomass* – can also lessen Pakistan's sufficient deficit in energy trade, as well as offer firms in the country globally competitive prices in the long-run. In light of the latest evidence, it is important to examine the relationship between the RE share of overall energy utilization, GDP per capita and harmful emissions.

3. Methodology and Data

We carry out two exercises to examine the relationship between renewable energy GDP per capita, and harmful emissions. The first focuses on tracking the significance of green energy and trends in energy wastage. Simple two-way relationships are analysed graphically to establish changes in energy sources and usage. The emphasis is on comparing trends in the shift to RE, and trends in emission-intensity of two hazardous gases, *viz*., GHG and CO_2. World Bank (2018) data was deployed to examine these trends.In doing so we avoided the use of energy prices and exchange rates because of the lack of consistent prices. Nonetheless, even though prices of renewable energy has fallen swiftly over the years, coal, oil and gas prices have remained significantly lower in the period 2018-2020 (Karberger, 2018; IEA, 2020).Exchange rates were also dropped because the members in the country panel obtainthe entirety of their renewable energy from domestic sources.

The second exercise tests econometrically the relationships between RE and GDP on GHG and CO_2 using the following two models:

$$\text{GHG} = \beta_0 + \beta_1 GDP + \beta_2 RE + u_t \qquad \text{(a)}$$

$$CO_2 = \phi_0 + \phi_1 GDP + \phi_2 RE + u_t \quad \text{(b)}$$

Modeling GHG with GDP and renewable energy is considered a simple yet robust approach to examine the associations between GDP, RE, and GHG, andhas been previously used by many studies like Vasylieva et al., (2020), Baležentiset al.,(2019), and Baloch et al.,(2019). The models are also theoretically supported by the Environmental Kuznet Curve (EKC), which provides the theoretical foundations to link the GDP and renewable energy with CO2 emission and GHG (Apergis& Ozturk, 2015). Rather than simply analyzing the above using Pakistan as an example, we compare Pakistan's experience with five East and Southeast Asian countries, that are: Malaysia, Thailand, Republic of Korea, Japan, and China. Using time series data from 1960 to 2016, data for the following variables were obtained from World Bank (2018):

i. GHG emissions per capita (kt of CO_2 equivalent)
ii. Fossil fuel energy consumption (% of total)
iii. Renewable energy consumption (% of total final energy consumption)
iv. CO_2 emissions in kilogram per USD GDP using 2010 prices.

Table 1 presents the abbreviations of the different variables used in the paper.

Table 1: Description of Variables

Variable	Abbreviation
GDP per capita	GDP
Greenhouse Gas emission per capita	GHG
Carbon Dioxide	CO_2
Renewable energy as the proportion in total energy	RE

While modeling panel data, researchers have two options: pooled regression or panel regression. In the case of the former, researchers do not need to consider the variance across cross-sections or time series. However, when it is intended to check whether the model has a random effect or fixedeffect, panel co-integration appears to be the most suitable approach for analysis (Chandran &Tang, 2013). Weadopted the model specified by Chandran and Tang (2013), (which was developed from

Engle &Granger, 1987),to examine the effect of GDP and RE on GHG and CO_2 emissions. We deployed panelco-integration techniques to estimate the short- and long-term co-integration among the modeled variables. Before examining the existence of co-integration, we first checked the level of stationarity of each variable by applying a panel unit root test. After performing the unit root test, we applied the pooled mean-grouped (PMG) estimator, as demonstrated by Pesaran et al. (1999) to estimate the panel co-integration. In the PMG estimates, short-run coefficients and error variances can fluctuate by keeping the long-run coefficients to be identical. Since the mean-group estimator (MG) does not allow coefficients and variances to vary, Pesaran and Smith (1995) developed the PMG estimator by modifying the MG. Whether the MG or PMG should be used for analyzing the co-integration depends upon the Hausman test statistic. If the Hausman null hypothesis is rejected then the MG estimator is preferred. Otherwise, the PMG estimator is the most appropriate for the analysis. As demonstrated in equation 1, panel co-integration can be deployed for estimation regardless of the level of integration of individual variables. Panel ARDL provides short and long term results simultaneously by allowing the selection of a suitable number of lags according to the selection criteria (equation 2).

$$\gamma_{nt} = \partial_{it} + \beta_{nt} X_{nt} + \upsilon_{nt} \ldots\ldots \quad (1)$$

$$\gamma_{nt} = \partial_{nt} + \sum_{n=1}^{j} \lambda_{ik}\, \gamma_{k,t-n} + \sum_{n=0}^{p} \beta_{ik}\, X_{k,t-n} + \upsilon_{nt} \ldots \quad (2)$$

In equation (1), n = 1, . . . , n is the country index, t = 1, . . . , T is the time index and υ_{nt} a random disturbance term. Equation (2) lays outthe assumptions about the parameters, the error terms and the exogeneity of the regressors.

The two fundamental equations we formulate to test in the second exercise are i) the relationship of GDP and the composition of RE in total energy consumption on GHG emissions; and ii) the relationship of GDP and the composition of RE in total energy consumption on CO_2 emissions.

4. Energy Transition Experiences

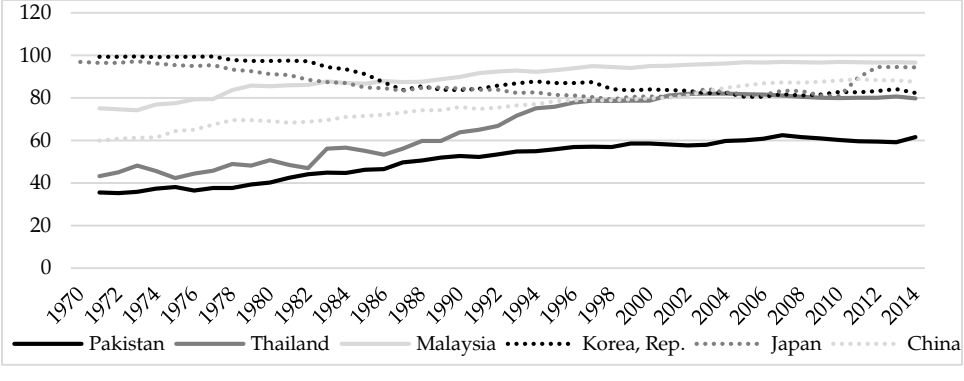
A major goal of the UNFCCC is to stimulate a shift from fossil fuels torenewable energy. The data available allows the comparative

assessment of fossil fuel composition of energy consumption, and GHG andCO_2 emissions, and the share of renewable energy consumption in total fuel consumption, and hydroelectric power consumption. Hence, we compare Pakistan's trends with selected East Asian economies with the purpose of assessing greening trends occurring in these economies.

Fossil Fuel Energy Consumption

Fossil fuels, drawn from oil, gas, and coal, are non-renewable resources are at the heart of the debate on dangerous carbon emissions. Also, it takes millions of years to form with these reserves, which aredepleteddrastically. Figure 1 shows Pakistan's dependence on hydrocarbons, which has grown immensely, resulting in a burgeoning import bill. According to the Economic Survey 2016-17, the domestic production of crude oil stood at 24.2 million barrels during nine monthsof fiscal year 2017. Due to the sudden increase in CNG usage, the current supply of natural gas is not meeting the energy demand in the gas sector. Pakistan is also suffering major shortages of oil, gas, and electricity. The reason behind is improper channelling of energy, insufficientexploration activities in the oil and gas sector, inappropriate distribution of resources, poor management, law and order situation, and bad governance. In this vein, Pakistan can learn a lesson from the Republic of Korea. The country has managed to not only reduce its fossil fuel energy consumption but has also kept it down despite a steep increase in overall energy generation. The country managed to also increase renewable energy resources.

Figure 1: Fossil fuel in Total Energy Consumption, Selected Nations, 1970-2014 (%)

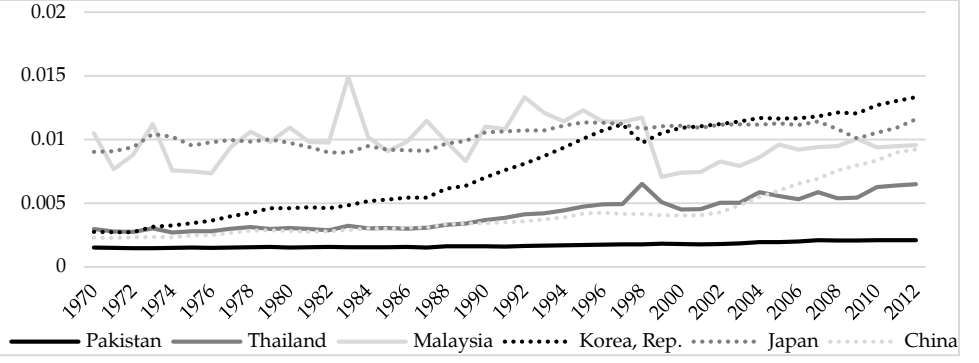


Source: Plotted from World Bank (2018).

Greenhouse gas emissions

Figure 2 compares Pakistan's greenhouse emissions with East Asian countries. Although Pakistan is not yeta significant contributor to global warming, its emissions derived from the energy sector (mainly from electricity generation, manufacturing, and transport) comes to be a main source of GHG emissions. In the energy sector of Pakistan, total fossil fuel consumption in 2012 was 47.96 Mtoe. Out of this, 14.19 Mtoe was consumed in the power sector for electricity generation, 13.26 Mtoe in the manufacturing sector, 10.06 Mtoe in the transport sector, 1.24 Mtoe in commercial/institutional sector, 6.46 Mtoe in the household sector and 2.75 Mtoe in the agriculture sector (HDIP 2013; Pak-IEM 2011). Pakistan emitted 361 million metric tons (MtCO2e) in 2017, with the energy sector contributing 46 percent to overall emissions, followed by agriculture (41 percent), land-use change and forestry (6 percent), industrial processes (5 percent) and waste (2 percent). Greenhouse gas emissions increased by 87 percent from 1990 - 2012, primarily due to energy and agriculture sector emissions. According to a preliminary projection, the GHG emissions levels for Pakistan are expected to increase many times in the coming decades. Pakistan aims to reduce its 2030 projected GHG emissionsby 20 percent, amounting to 1603 million ton of carbon dioxide equivalent subject to the availability of international grants to meet the total abatement cost for reduction which amountsto about US$ 40 billion at current prices. According to government sources, Pakistan submitted its Intended Nationally Determined Contribution (Pak-INDC), under Article 2 of the Paris Agreement, to the United Nations Framework Convention on Climate Change (UNFCC). Under the INDC, Pakistan's adaptation needs range between US $7 to US $14 billion per annum during this period. In this vein, Pakistan can learn from the experience of Malaysia and China. While there is upward trend of GHG emission in most countires, in Malaysia the trend has become relatively flat. This happened due to the Malaysian government’s policies to adopt low-carbon development measures. Prominent among such measures was carbon capture and storage (CCS), which focuses on securing and storing carbon dioxide emissions before they are released into the atmosphere. Although this technology is still in its early stages, countries are committed to implementing variations of it with both bilateral and multilateral cooperation underway.

Figure 2: Total Greenhouse Gas Emissions Per Capita, Selected Nations, 1970-2012 (kt of CO_2equivalent)

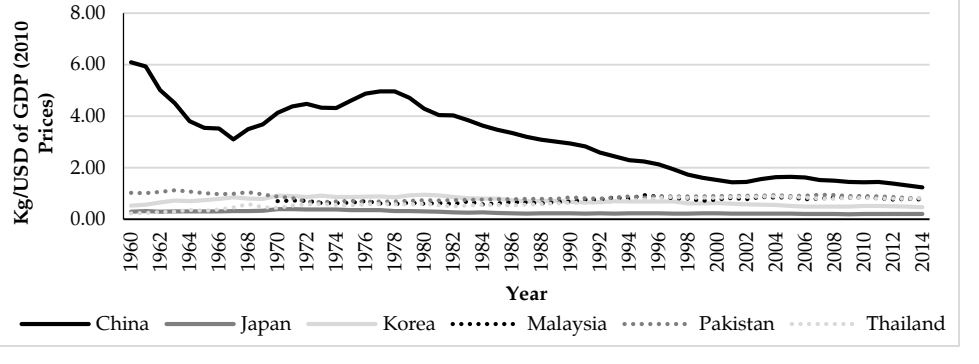


Source: Plotted from World Bank (2018).

Carbon Dioxide Emissions

We used CO_2 emissions in kilograms per unit of GDP as a proxy of CO_2-intensity of GDP deflated at 2010 prices in USD. China has been the largest emitter of CO_2 emissions among the countries compared (Figure 3). With its early focus to shift towards green energy, Japan has the lowest emissions ofall the countries. South Korea has followed suit since the 1980s to show the second-lowest emissions per unit of GDP. Pakistan is bunched with Malaysia and Thailand with similar CO_2 intensities per unit of GDP. However, while the CO_2 intensities of GDP of Japan, South Korea and China show a trend fall, thoseof Malaysia, Pakistan, and Thailand have risen since the 1980s.

Figure 3: Carbon Dioxide Emissions, Selected Asian Nations, 1960-2014

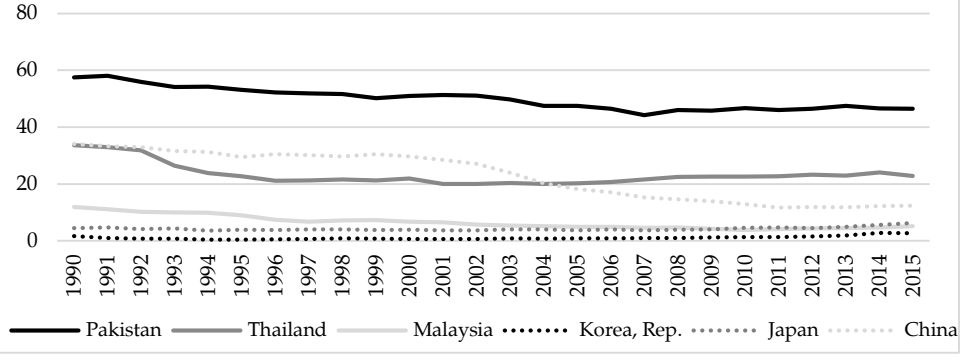


Source: Plotted from World Bank (2018).

Renewable Energy

Following the Paris Accord of 2015, most members of the United States submitted Intended Nationally Determined Contribution (INDC) to gradually replace fossil fuels with RE (UNFCCC, 2016). Pakistan and the East Asian countries were among the countries who pledged to increase the use of RE to 45 percent by 2030 with 10 percentcoming from technology transfer from developed countries. Figure 4 shows the share of RE in total fuel consumption over the period 1990-2015. Pakistan (46 percent) shows the highest share of RE use followed by Thailand (23 percent) and China (12 percent) in 2015. Japan (6 percent) and South Korea (3 percent) showed low intensity of RE use in 2015.

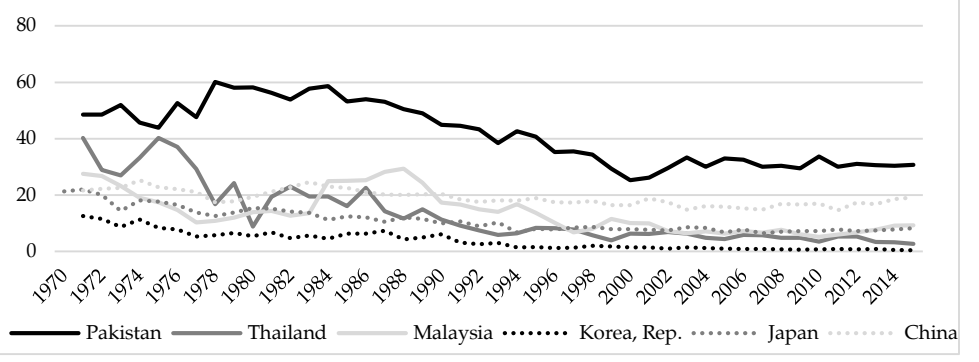
Figure 4: Renewable Energy in Total Energy Consumption, Selected Nations, 1990-2015 (%)



Source: Plotted from World Bank (2018).

Pakistan's vast RE resources largely comes from hydropower (Figure 5). Hydropower accounted for 31 percentof electricity produced in Pakistan followed by China (19 percent) and Malaysia (9 percent) in 2015. Japan (8 percent), Thailand (2 percent) and South Korea (almost zero) showed the least use of hydropower to produce electricity.The country's dependency on hydro can be attributed to the endowment of the rich Indus river and tributaries. Pakistan has constructed two major dams on its two prime rivers and the government plans to build two more dams.

Figure 5: Electricity production from hydropower, Selected Nations, 1970-2015

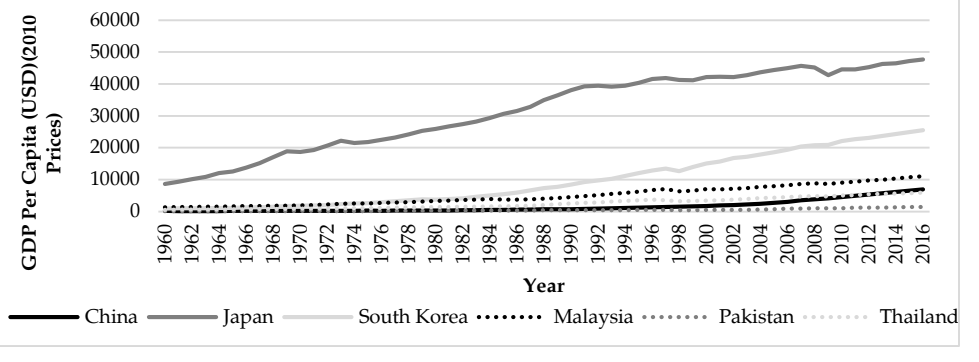


Source: Plotted from World Bank (2018).

Per Capita GDP

As shown in Figure 6, Pakistan has a lower GDP per capita as compared to China, Japan, South Korea, Malaysia, and Thailand.[3] Even more serious is the rate of increase inPakistani GDP per capita, which is the lowest among these selected countries. Its GDP per capita has grown significantly more slowly than the GDP per capital of the East Asian economies. Such a low annual average GDP per capita growth rate obviously means that the country will have to steeply increase energy sources for it to fuel an economic catch up with the East Asian economies.

Figure 6: GDP Per capita, Selected Nations, 1960-2016



Source: Plotted from World Bank (2018).

[3] We preferred the constant prices in USD over local currencies to compare the GDP per capita of Pakistan with the East Asian economies.

While access to hydropower has allowed Pakistan higherRE shares, its total energy consumption is significantly lower than the East Asian economies, and rapid economic growth is likely to change the picture significantly. Its per capita GDP is still much lower than that of China, Malaysia, Korea, Thailand and Japan. Unless the country manages to further expand its RE supply, rapid economic growth may change the energy composition adversely to skew towards non-RE. In the next section, we examine if there exists a positive and causal relationship between GDP per capita growth and the share of RE in total energy emissions with two key hazardous gases as proxies of non-RE energy, i.e. GHD and CO_2.

5. Statistical Analysis

This section focuses on the impact of GDP per capita growth and the increasing share of RE on GHG and CO_2 emissions. The results will be important to examine the potential impact of acceleratedPakistan's GDP growth, which will be necessary if the country is to catch up with the East Asian economies.

Unit root tests

To examine the stationarity of the variables, we deployed two tests, namely Im, Pesaran and Shin test (Im et al., 2003) and Levin, Lin and Chu test (Levin etal., 2002). Both IPS and LLC tests have the assumption of common unit root processes across cross-sections. The results of the Panel Unit Root test at levels and first differences appear in Table 2. The results show that all variables are stationary at first difference. This in turn shows the suitability of a Panel-ARDL approach for estimating our models.

Table 2: Unit Root Tests

Variable	Level		1st difference	
	LLC	IPS	LLC	IPS
GDPPC	0.014	0.024*	-4.58	-3.17*
GHG	3.481	2.45*	-3.94	-3.72*
RENE	0.406	2.12*	-2.62	-4.05*
CO2	0.373	0.521*	-4.21	-3.88*

Note: *LLC stands for Levin, Lin & Chu test (LLC) &IPS forIm, Pesaran, and Shin W-stat test (IPS). Values in parentheses are p-values where *, **, *** represent 1%, 5%, and 10% respectively.*
Source: Computed using World Bank (2018) data.

Panel Co-integration tests

In order to determine whether long-run relationships exist among variables or not, we applied a panel co-integration test using the Pedroni (2004) process. The results of panel co-integration of both models are exhibited in Table 3. The results show that among the seven-panel integration tests, six reject the null- hypothesis of no co-integration at the 1 percent level of significance. Likewise, in regards to the case of an intercept and a linear trend, five-panel co-integration tests reject the null hypothesis of no co-integration at the 1% significance level. Furthermore, the panel co-integration results exhibited in Table 3 also show the existence of co-integration among the modeled variables. A total of five out of six-panel co-integration tests reject the null hypothesis of no co-integrationat the 1 percent level. On the basis of these results, we safely inferco-integration among variables in both models.

Table 3: Panel Co-integration Test

Dependent variable	**Greenhouse Gas Emission (GHG)**		**CO2 Emission**	
Variable	**Statistics**	**Weighted**	**Statistics**	**Weighted**
Pedroni Residual Co-integration Test				
Alternative hypothesis: common AR coefficients (within dimension):				
Panel v	-0.89	2.14	-0.78	2.31
Panel rho	2.10	1.15	1.95	1.39
Panel PP	-1.64**	3.84*	-1.83**	4.01*
Panel ADF	-1.72**	2.71*	-1.69**	2.44*
Alternative hypothesis: common AR coefficients. (between dimension):				
Group rho	2.34**		2.57**	
Group PP	-8.41*		6.53*	
Group ADF	-2.66**		3.01*	

Note: *Values in parentheses are p-values where *, **, *** represent 1%, 5%, and 10% respectively.*
Source: Computed using World Bank (2018) data.

Long Run and Short Run Estimates

In order to test the existence of short- and long-run relationships among the modeled variables, we deployed three tests, namely mean group (MG), pooled mean group (PMG), and dynamic or difference fixed effect (DFE) tests. For the PMG estimator, the long run coefficient must be homogenous by group for the PMG estimator tobe consistent. On the other

hand, ifthe model is heterogeneous, the MG estimator would be consistent. In order to choose between the MG and PMG estimators, we used the Hausman test for long-run homogeneity (Table 4, Table 5). The test statistics value of the Model 1 Hausman test is 4.38, with a probability value of 0.251, which implies that the null hypothesis for cross sections are homogenous cannot be rejected. This means that PMG is the most efficient estimator in our analysis. The long run estimation results of PMG are presented in Table 3, which shows that GDP has a significant and positive relationship with GHG whereas RE has a significant and negative relationship with GHG at the 1 percent statistical level in the long run. Remarkably, GDP per capita's long-run elasticity coefficient is 1.03, indicating that a one percent rise in GDP will raise GHG per capita by 1.03 percent.

Further, RE consumption's coefficient value is 0.04, which demonstrates that a one percent increase in RE consumption will reduceGHG by 0.04percent. Further, in model 2, the long-run elasticity estimate of GDP per capita and REportrays a similar picture. The GDP per capita value is just above the unity (1.01), implyinga 1.01 percent increase in CO_2 per capita whenGDP per capita increases by one percent. Likewise, the results of renewable energy show a one percent increase in renewable energy can decrease CO_2 emissions by .09 percent.

The values of ECT (error correction term) for both models are computed next. The ECT value of model 1 is −0.196, which is negative and significant (Table 4). It implies that a shock to the carbon emissions equations leads to an adjustment of almost 20 percentwithin the first year, and it takes approximately 5 years to converge to the long-run equilibrium level. Likewise, the ECT value of 0.16 formodel 2 shows that in case of a shock to the GHG equation, there is a 16 percentadjustment towards the long run equilibriumin the first year.

Table 4: Hausman Test of Homogenity

Variables	Model 1		Model 2	
	Panel PMG	MG	Panel PMG	MG
GDPPC	1.032	2.11	1.012	1.23
RE	0.022	0.31	0.09	0.18
Hausman MG Test	4.38 (0.251)		3.47 (0.217)	

Source: *Computed using World Bank (2018) data.*

The ECT of the countries, for both models, are presented in Table 5. In model 1, the ECT coefficient value shows that Thailand has the fastest speed of adjustment with an ECT coefficient value of 0.35 while Japan has thelowest. Our results support the pollution haloes hypothesis and are in line with the findings of Mazzanti and Zoboli (2005). However, our results contradict the findings of Tamazian et al. (2009) and Seker et al. (2015).

Table 5: Long Run and Short Run Results based on PMG Estimator

Variables	Model 1		Model 2	
	Coefficient	p-value	Coefficient	p-value
Long Run				
GDPPC	1.032	0.000	10.012	0.000
RENE	0.022	0.000	0.09	0.000
Short Run				
ECT	-0.196	0.000	-0.16	0.000
Δ*ln*GDPPC	0.272	0.000	0.215	0.000
Δ*ln*REN	0.011	0.000	0.009	0.000
Constant				
ECT for each country				
Pakistan	-0.31	0.000	-0.27	0.000
Thailand	-0.35	0.000	-0.36	0.000
Malaysia	-0.29	0.000	-0.22	0.000
China	-0.22	0.000	-0.25	0.000
Japan	-0.16	0.000	-0.19	0.000
Korea	-0.27	0.000	-0.21	0.000

Source: Computed using World Bank, 2018 data.

A significant long-run relationship exists between GHG, GDP and RE, which indicates the existence of causality among these variables. In order to test this, we applied panelGranger causality tests. The results are shown in Table 6. Two important relationships can be noted from results. First, the significant short-run causality of CO_2 emission to renewable energy (RE) and, second, greenhouse gas emission to renewable energy. Furthernmore, our results show that GDP has short-run causation with GHG and CO_2 emissions. Our results also show a short run significant bilateral causation between GDP- CO_2 emission, and GHG-GDP. From the causality results, it can be inferred that GDP growth needs fossil energy, which further emits CO_2. The interesting fact is that usage of fossil fuel

energy and CO_2 emissions encourage renewable energy consumption. These results concur with the studies ofOcal and Aslan, (2013), and Pao and Tsai, (2011). These studies found a bidirectional relationship between GDP and CO_2 emissions.

Table 6: Panel Causality Test

	F-statistics
lnGDP→ GHG	3.05*
lnGHG→LnGDP	1.25
lnGDP→LnCO_2	2.98*
lnCO_2→lnGDP	3.41*
lnRE→ lnCO_2	2.05
lnCO_2→lnRE	5.37*
lnRE→ GHG	1.50
lnGHG→lnRE	4.62*

Source: Computed using World Bank (2018), data.

Overall, there is arestrong short- and long-run causality relationshipsbetween GDP per capita and RE on GHG and CO_2 emissions. The key results from this exercise are that accelarating GDP growth will further exacerbate emissions of GHG and CO_2. Hence, even though Pakistan has relied more on RE in powering GDP growth than Japan, South Korea, Malaysia, China, and Thailand, efforts must be taken to develop RE further so as not to accelerate the use of non-renewable sources of energy in the future.

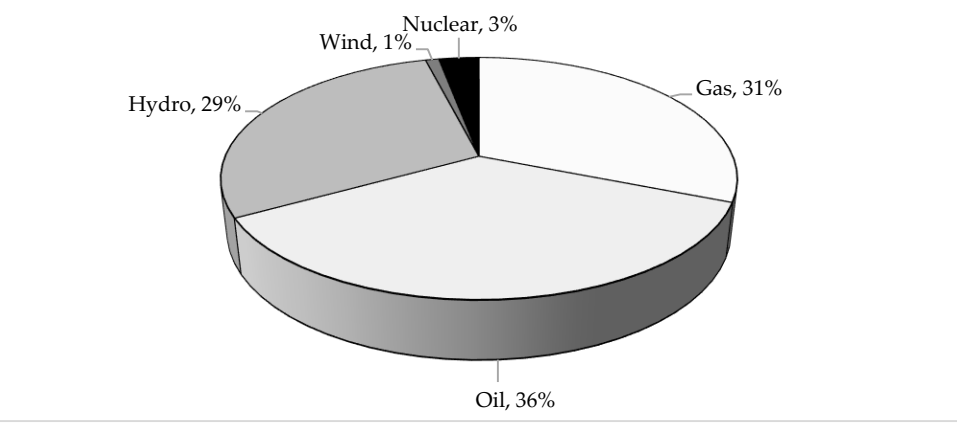
6. Implications for Pakistan

Having established a strong and positive link between GDP per capita and GHG and CO_2 emissions, we examine the policies Pakistan should adopt to avert the hazardous path that East Asian economies had taken to achieve rapid economic growth. Clearly, the government will have to develop its RE sources to ensure that its rapid economic growth will not exacerbate its current RE intensity in energy consumption. Pakistan primarily generates electricityfrom hydro and thermal resources (see Figure 7) and a small amount of energy is also produced through nuclear sources. The thermal resourcesaremainly drawn from non-renewable sources, such as coal, gas, and diesel, for producing electricity. Hydropower generation was second contributing about30 percentin 2015.

The Water and Power Development Authority (WAPDA) generates hydropower with an installed capacity of around 6556.4 MW. Nuclear power contributed 4.9 percent of the total energy supply in Pakistan. This source shouldonly be expanded with caution given the potential for catastrophes like those that occurred in Chernobyl and Fukushima (Britannica, 2020;Sugiyama, 2019).Figure 1 shows that renewable energy production's global installed capacity has shown an increasing trend with 147GW in the year 2018.

While the provision of electricity to the masses in Pakistan has shown exponential growth,it is stillsignficantly insufficient. With an acute power shortage of around 3-5 GW, the percentage of the population enjoying electricity is between 60 and65 percent (Menanteau et al., 2003). Although Pakistan has an abundant supply of renewable energy, efforts to increase the use of these resources for energy generation have been insufficient. Hydropower is the major source of sustainable energy produced in Pakistan. Figure 7 shows that in Pakistan, 67 percent of energy production was estimated to come from oil and gas, hydro 29 percent, nuclear 3 percent, and wind 0.5 percentin 2017 (Kamran 2018).

Figure 7: Pakistan's Energy Mix, 2015



Source: Kamran (2018).

The first initiative to reform the energy sector of Pakistan can be traced to 1980 when the government took heed of widespread power shortages to devise a policy to attract the private sector to develop RE. In 1983-88, and in 1994-98, the government spent PRs14 million to promote research and development in solar energy resources. The failure of these initiatives led to the government launching a power policy in 2002 to produce 500MW and 1000MW of alternative energy resources (with the exclusion of hydropower) by 2015 and 2020 respectively (Kaundinya et al.,2009). However, the policy initiative failed to attract private investment (Baily, 2003).During this period, the government also tried to develop renewable energy technologies. The government established the National Institute of Silicon Technology (NIST) and the Pakistan Council of Appropriate Technology (PCAT) in 1981 and 1985, respectively, which aimed to embolden, facilitate and develop RE technologies for producing hydro, solar, and wind energy. These institutions failed to perfrom and were merged into the Pakistan Council of Renewable Technology (PCRET) in 2002. The newly formed organization was formed to collaborate, manage, and grow research activities purely in the renewable sector. The government also formed the Alternative Energy Development Board (AEDB) in 2002 with the objective of developing new technologies for producing solar, hydro and wind power (Yazdani &Rutherford, 2010).

The failure of the earlier policies led to the launching of the Development of Renewable Energy for Power Generation Policy 2006.

The policy aimed to support and develop renewable energy projects and technologies to meet at least 10 percentof Pakistan's energy demand by 2015. This policy specifically focused on micro- and meso-level projects of hydro, solar, and wind energy (Bhutta, 2008). However, this policy has only been marginally successful. The few projects that managed to generate power include the 100 MW Quaid-e-Azam solar park and the 50 MW wind energy production.

Pakistan's geographical landscape makes it an excellent location for the development and installation of solar energy projects. The country gets around 15.5 x 1014kwh of solar irradiance annually, which has the capacity to produce 1600GW of power every year that could be the leading source of power production in Pakistan (Mendonça, 2009). Similarly, Pakistan receives heavy winds in the South with 6–8 m/s on average wind speed in the coastal provinces of Sindh and Baluchistan. These winds have the capacity to generate 122.7 GW power annually. Even though this capacity is much less than that of solar, its importance cannot be understated. Also, hydropower produced in the country already accounts for around 29 percentof overall energy consumption in 2017 (Kamran, 2018).

The potential ofwind energy for Pakistan can be assessed from developments in other countries. China is farahead of other countries,having developed various sources of energy through clear policies to support rapid economic growth (see Table 7). Pakistan's neighbor, India, has also forged ahead to rank 4th in the world in wind energy. Existing studies on renewable energy sources do not provide detailed insight into the various dimensions of renewable projects in Pakistan. The case of wind potential can be put as an example. Recent statistics show that Pakistan has the potential to produce a huge amount of energy from its widely prevalent wind resources as compared to India. It is importantthat Pakistan’s government install windmills in the South to generate wind power, which can be appropriated both during the day and in the night so long as the winds read a certain minimum force.

Table 7: Top ten countries producing energy from wind, 2010

Country	MW	%Share
PR China	145,362	33.6
USA	74,471	17.2
Germany	44,947	10.4
India	25,088	5.8
Spain	23,025	5.3
United Kingdom	13,603	3.1
Canada	11,205	2.6
France	10,358	2.4
Italy	8,958	2.1
Brazil	8,715	2.0
Rest of the World	67,151	15.5
Total Top 10	365,731	84.5
World Total	432,883	100

Source:*World Bank (2010).*

The Pakistanigovernment will have to review existing RE policies using the example of countries like China and Malaysiato adapt rather than copy successful RE policies in order to move the green energy agenda forward. It will not only help to power GDP growth andcatch up with the East Asian economies but also ensure that the environment is not compromised.

7. Conclusions

For all the potential Pakistan has, its economic growth has been low compared to the East Asian economies. While the country has yet to provide an adequate supply of power to its population, concerns over climate change and global warming haveopened up new alternatives that offer Pakistan the opportunity to develop RE from solar and wind.Although Pakistan's consumption of fossil fuels in total energy consumption – including natural gas - is lowcompared to East Asian economies, the intensity of fossil fuels consumed has risen steeply over the years. Our panel Granger causality tests using Pakistan, China, Japan, South Korea, Malaysia, and Thailand show that GHG and CO_2 emissions would rise rapidly if there is any acceleration in GDP growth. Yet, Pakistan has to step up GDP growth to catch up with the East Asian economies.

Consequently, there is a need to develop the abundant solar and wind endowments Pakistan has to fuel rapid economic growth.

In addition,to step up the production of energy from solar and wind sources, Pakistan should attempt to regulate the energy sector to ensure that it is adequate to offer low prices, uninterrupted supply, and able to sustain the shift from fossil to non-fossil fuels. An energy master plan accompanied by five-year reviews would be helpful to achieve this cause. The master plan should push for a sharp expansion in energy supply if the government's plan to stimulate rapid economic growth is to be realized. The manufacturing sector is the most energy-intensive sector among the sectors that make up GDP. Since energy cannot be stored effectively, the plan should also lay out the rules for developing a demand-supply framework that on the one hand should be internationally competitive for industrial users and fair to the normal consumers, and on the other hand, be accessible to those whose needs cannot be translated into significantly higher demand owing to low incomes. Energy is a public utility that is excludable and rivalrous but yet needs to reach everyone.

Future studies should include the impact of prices of the different energy resources and exchange rates, especially for countries such as Pakistan, which is often afflicted with Dutch Disease problems that raise fuel prices facing domestic consumers. Given that energy is an important component of inputs used by most industries and consumers, and because Pakistan is a net importer of oil and gas, an analysis of the impact of exchange rate appreciations (and the accompanying inflationary impacts) is an important avenue of research.

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Are Agricultural Markets in the Punjab Technically Efficient?*

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Abstract

We test the technical efficiency, measured by the degree of integration,of agriculture markets for five crops in the Punjab province of Pakistan using daily wholesale market prices from the Agriculture Management Information System (AMIS). We find that potato, onion and mango markets are well integrated both horizontally and vertically, with the speed of price adjustment in most cases (mango is the exception) being very rapid. We also find that kinnow and basmati rice markets are both vertically fairly well integrated. Furthermore, we find that trends in cropping patterns over the period 2000 to 2014 are in line with the changing market demand and government price interventions. The reforms introduced by the Punjab Agriculture Marketing Regulatory Authority (PAMRA) Act 2020, aimed at increasing competition in agriculture markets, have the potential to significantly improve economic efficiency.

Keywords: Agricultural prices, market integration, price transmission, market efficiency, agriculture marketing.

JEL Classification: Q110, Q111, Q113 and C110

1. Introduction

Agriculture plays a significant role in economic development not only for ensuring food and nutritional security but is the major source of rural employment and contributes substantially to earnings from exports.

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While the relative importance of agriculture has been declining in South Asia, it is still considerable. The agriculture sector contributes about 40 percent of total employment in Bangladesh, India and Pakistan, and over 50 percent in Bhutan and Nepal (International Labor Organization, 2018)[1]. Agriculture also accounts for over 20 percent of GDP in Pakistan and Nepal, and about 15 percent in Bangladesh, Bhutan and India (World Development Indicators, 2018)[2].

In Pakistan, agricultural sector growth has slowed significantly since 2000, with the slowdown being greater in the crops sub-sector (see Figure 1)[3]. There is no consensus on why the decline in the growth rate has occurred, but factors such as "inequality in farm sizes, limited investment in irrigation systems, the slowing of adoption of new technology and techniques and a weak extension service" have been cited as likely causes (Valdes, 2013).

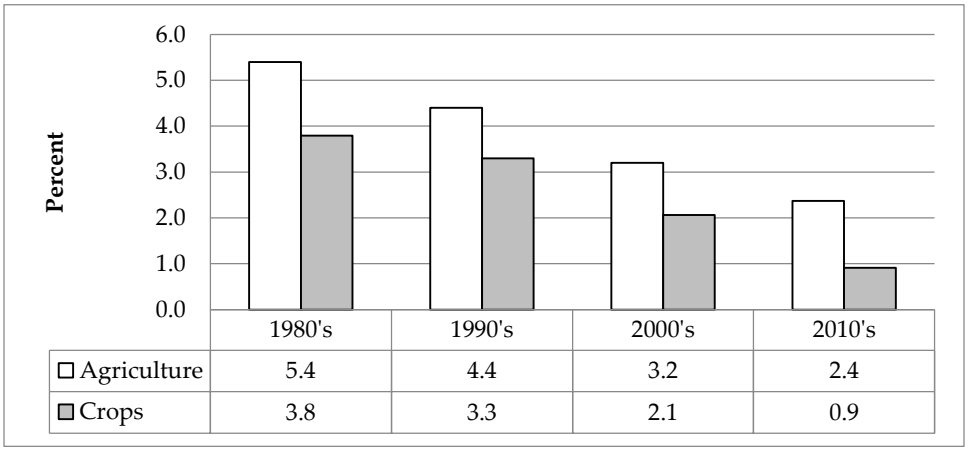
We suggest that the lack of efficiency of agricultural markets is an additional factor responsible for this slowdown. We know that there are multiple players at each stage of the agricultural marketing chain, that the legal and regulatory framework of agricultural markets in the Punjab (and the rest of the country) is archaic (Ahsan 2018) and that marketing margins are high[4]. It is our view that inefficient agricultural markets could be eroding the incentives for the producers to invest in productivity enhancing inputs and technologies. We posit that market efficiency can be divided into two components, i.e. economic efficiency and technical efficiency.

An *economically efficient* agricultural marketing system, defined as a system where competition throughout the marketing chain, results in *total marketing costs* of agricultural products being minimized and profits earned by each of the players in the marketing chain being no more than normal; and a *technically efficient* agricultural market being defined as one where the various agricultural markets in the region are well integrated.

[1] https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS
[2] http://wdi.worldbank.org/table/4.2
[3] Agricultural growth has been declining since the 1990s, but it was still fairly healthy until 2000.
[4] According to the World Bank, prior to the recent [in 2020] reforms "Farmers' produce used to pass through seven or eight different hands before reaching the consumer. Consequently, market margins were high, but producers were left with little" (https://blogs.worldbank.org/endpovertyinsouthasia/modernizing-punjabs-farming-benefit-farmers-and-consumers)

In this article, we will focus on testing for *technical efficiency* of the agricultural marketing system because, unfortunately, due to the lack of data on farm gate prices and margins at different stages of the marketing chain it is difficult for us to say much about its *economic efficiency*.[5]

Figure 1: Historical Growth Rates for Pakistan's Agriculture and Crops



	1980's	1990's	2000's	2010's
Agriculture	5.4	4.4	3.2	2.4
Crops	3.8	3.3	2.1	0.9

Source: Pakistan Economic Survey (1980-2016).

Market integration has been defined as the tradability or contestability between markets (Barret and Li, 2002). It can be interpreted as the extent to which price shocks are transmitted between spatially separate markets (Goodwin, 2006) and can be measured in terms of strength and speed of price transmission between markets across various regions of a country (Beag and Singla, 2014). Market integration is undoubtedly important because until agricultural markets are integrated, producers and consumers will not realize their potential gains (Reddy, 2012) and the degree to which consumers and producers can benefit depends on how domestic markets are integrated with world markets and how the regional markets are integrated with each (Varela et al., 2012).

[5] The *economic efficiency* of agricultural markets in the Punjab is expected to improve following the approval in March by the Punjab Assembly of the PAMRA Act—short for Punjab Agriculture Marketing Regulatory Authority Act 2020. The new law establishes a more transparent legal regime to market agricultural produce to help safeguard the free flow of crops and stimulate food supply (https://blogs.worldbank.org/endpovertyinsouthasia/modernizing-punjabs-farming-benefit-farmers-and-consumers).

The concept of market integration is often used as a measure of market efficiency; however, in our view it is more appropriate to think of it as a measure of the *'technical efficiency'* of a market; this is how we use it in this paper, with technical efficiency of the market for various crops being evaluated in terms of transmission of price information among the producer markets and between producer and consumer markets. Our research not only adds to our understanding of the working of the agriculture markets in Pakistan, but it also contributes to the overall literature on agricultural markets because our analysis of market integration is based on a unique data set that has daily price information, in contrast to most of the existing research on integration in agricultural product markets, which is based on analysis of monthly price data[6].

We selected five crops for analysis, namely, potato, onion, mango, kinnow and basmati rice. To test for strength and speed of price transmission between agricultural markets, we use vector auto regressive (VAR) models. It is seen that potato, onion and mango markets are well integrated both horizontally and vertically, with the speed of price adjustment in most cases (mango is the exception) being very rapid. Therefore, we can say that these three markets are technically efficient. As far as kinnow and basmati rice markets are concerned, both are vertically fairly well integrated but we are unable to satisfactorily measure the extent of horizontal integration due to lack of data.

In Section 2, we review the literature on market integration from the perspective of methodologies used and the extent of market integration estimated for different crops in other countries. Section 3 provides a description of the data and research methodology and in Section 4 we discuss the results. Section 5 provides a reality check on the impact of efficient agricultural markets and Section 6 concludes.

2. Review of Literature

There is considerable literature on market integration and price transmission. Markets are said to be integrated when a price increase or

[6] Kinnucan and Forker, 1987; Goletti, Ahmed &Farid, 1995; Parsley and Wei, 1996; Dawson and Dey, 2002; Kaabia et al., 2002; Rapsomanikis et al., 2003; Goodwin and Holt, 2006; Weber and Lee, 2006; Trung *et al.*, 2007, Baulch 2008; Bakucs et al., 2013.

decrease (shock) is transmitted to vertically or between spatially connected distinct markets (Jena, 2016), whereas price transmission is the extent to which market shocks are transmitted up and down in the marketing chain (Goodwin, 2006). The degree to which a price shock in one market affects a price in another market can indicate whether efficient arbitrage exists between the two markets (Rapsomanikis et al., 2004).

Different authors have explained price transmission through two ways: 1) on the basis of the concept of the Law of One Price (Baffes, 1991; Yang et al., 2000) and 2) in terms of market integration, an approach that has been far more commonly used[7]. The Law of One Price (LOP) states, "In markets linked by trade and arbitrage, homogeneous goods will have a unique price, when expressed in the same currency, net of transaction costs" (Ibid, p. 83). Under market integration a further division that can be made is the extent of spatial and vertical market integration. "Spatial market integration refers to co-movement of prices, and more generally, to the smooth transmission of price signals and information across spatially separated markets" (Goletti et al., 1995). It implies that the difference between prices in different marketplaces will never exceed transaction costs (Listorti & Esposti, 2012). Vertical price transmission means movement of price along the supply chain from the consumer to the producer level (Rapsomanikis et al., 2004).

Studies on spatial market integration show how regional markets are linked using data on agricultural products. In the case of markets for cereals in developing countries, generally the evidence is of strong or perfect spatial integration (Dawson and Dey, 2002 for Bangladesh; Ghosh, 2003, Makama et al., 2016 for India; Zahid et al., 2007 for Pakistan; Baulch, 2008 for Vietnam); but in a few cases only weak evidence was found (Trung et al., 2007 for Vietnam). There were only a few studies on vegetables or fruit markets, but in those as well there is evidence of strong spatial integration (Ramadas et al, 2014, KC and Rajalaxmi, 2019, bothfor India).

[7] Ravallion, 1986; Palaskas and Harriss 1993; Gardner & Brooks, 1994; Baulch 1997; Dawson &Dey, 2002; Kaabia et al., 2002; Rapsomanikis et al., 2003; Ghosh, 2003; Weber & Lee, 2006; Trung et al., 2007; Zahid et al., 2007; Baulch, 2008; Bakus, 2013; Ramadas et al., 2014; Paul et al., 2015; Tadesse, 2016; Kharin et al., 2017; Usman & Haile, 2017; KC &Rajalaxmi, 2019; Ozturk, 2020.

Speaking of vertical price transmission, studies on vegetable markets found stable long run relationship between prices either between producer and consumer markets (Tadesse, 2016 for Ethiopia) or between export and domestic markets (Paul et al., 2015, for India). A few studies on cereals and grains market found weak evidence for vertical price transmission in the long run among domestic markets and domestic and international markets (Usman and Haile, 2017 for Ethiopia; Ozturk, 2020, for Turkey). A meta-analysis of European agriculture found that vertical price transmission is asymmetric in both the long and shortrun (Bakus, 2013). Studies on meat and dairy markets found vertical integration between the farm, wholesale and retail markets in the long run and full transmission of all supply and demand shocks to prices prevalent in the system (Kaabia et al., 2002, for Spain; Kharin et al., 2017, for Slovakia). The studies explaining price transmission base their results on monthly price data.

Studies on a variety of goods, both agriculture and non-agriculture, using quarterly data of prices, found that vertical price convergence takes place faster for tradable goods than for non-tradable goods (Yazgan and Yilmazkuday, 2011; Parsley and Wei, 1996, all for USA).

Studies on price transmission and market integration use numerous time series techniques. Techniques such as vector auto regressive and error correction models have become the standard instruments for investigating market relationships (Jena, 2016). While vector auto regressive (VAR) models check for size and speed of price adjustment among markets (Rapsomanikis et al., 2004), vector error correction (VECM) models check for long-run relationships mainly through the estimation of cointegration[8] among price series (Maitra, 2019). Both methods are used commonly in literature: Dawson and Dey, 2002, VAR; Ramadas et al., 2004, VAR; Baulch, 2008; Zahid et al., 2007; Trung et al., 2007; Tadesse, 2016; Usman and Haile, 2017; KC and Rajalaxmi, 2019; Ozturk, 2020, all use VECM.

[8] Cointegration implies the theoretical notion of a long run equilibrium relationship. If two price series are cointegrated, there is a trend of co-movement in the long run given their linear relationship. In the short run, the prices may vary, as shocks in one market may not be immediately transmitted to other markets or due to transportation delays, however, arbitration prospects confirm that these deviations from the long run equilibrium relationship are temporary" (Rapsomanikis et al., 2004, p. 58).

According to Rapsomanikis et al. (2004), a commonly used method to estimate causality between prices is the Granger causality test. It provides information on which direction, if any, price transmission is occurring between two series. If two markets were integrated, the price in one market would generally Granger-cause the price in the other market and vice versa. Two price series may deviate from one another because of factors such as transaction costs and yet Granger causality may exist since some price signals may be transmitted from one market to the other. However, lack of Granger causality may not indicate an absence of transmission since price signals may be transmitted immediately under special conditions. Causality tests commonly use post-market integration estimation, as in the following studies: Blank and Schmiesing, 1988; Baulch, 2008; Nazlioglu, 2011; Beag and Singla, 2014.

3. Data and Methodology

Data

Our research contributes to the literature by using a unique data set, the Agriculture Management Information System (AMIS)[9], that has daily price information of crops for the years 2010-17. This research will bridge the gap in literature by carrying out the following analysis using time-series economic modeling on the crop subsector including cereals (rice), fruits (mango and citrus) and vegetables (onion and potato): 1) checking for market integration through horizontal and vertical price transmission; that is, firstly whether price signals are being transmitted between production centers, and secondly whether price signals are being transferred from the consumer center to the producers and vice versa, respectively, using daily price data; and 2) understanding market efficiency, mainly by analyzing the speed at which horizontal and vertical price transmission takes places among the markets for the above mentioned crops.

The Agriculture Management Information System (AMIS) data set provides district-wise daily wholesale market price information. However, since AMIS reports price data only for districts in Punjab, the analysis unfortunately has to be restricted to this one province.

[9] http://amis.pk/

Restricting the analysis to Punjab does not invalidate our results since agricultural marketing is a provincial subject and Punjab accounts for over 75 percent of Pakistan's production of 4 out of the 5 selected crops (see table 1) and 53 percent of Pakistan's population, i.e., 110 million out of 208 million (Pakistan Bureau of Statistics[10], 2018). But it needs to be noted that the conclusions with regards to integration of agriculture markets of this analysis may not be fully applicable to rest of Pakistan, particularly as both agriculture markets and transport infrastructure in the Punjab are more developed than in the other the three provinces.

Table 1: Provincial Shares in Total Pakistan Production (000 ' tonnes) for 2016-2017

Crop	Punjab	Sindh	Baluchistan	Khyber Pakhtunkhwa	Pakistan	Punjab's % share in Total Production
Potato	3660	6	22	143	3831	96
Onion	370	748	532	184	1833	20
Mango	1375	405	1	3	1784	77
Citrus	2117	26	7	30	2180	97
Basmati Rice	2524	78	95	42	2739	92

Source: Agricultural Statistics of Pakistan 2017-18 (2019), Ministry of National Food Security & Research Islamabad.

In the analysis, we look at crops in three categories of agricultural produce: cereals (rice), fruits (kinnow[11] and mangos) and vegetables (onions and potatoes). These items are selected because these are important crops in each category, both with regards to the country's agricultural production and exports (Ministry of National Food Security and Research, 2019a) and the regularity of data reported in the AMIS system. Even though wheat is the most important crop in Pakistan, it has not been included in our analysis because the government intervenes in the wheat market through a minimum support price (MSP) policy, which would bias any analysis of the market price data.[12]

[10] http://www.pbs.gov.pk/content/provisional-summary-results-6th-population-and-housing-census-2017-0

[11] Kinnow which is similar to a mandarin orange is the dominant form of citrus gown in Pakistan

[12] Under the support price program, the government usually announces a MSP in November, procures a substantial share of the output during the harvest period (April to June) and releases it to the flour mills during the lean season (December to March).

The daily prices of products are available for an 8-year period from 2010 to 2017[13]. The data provides market price values for weekdays only and the reported prices of rice, mangos, onions and potatoes are per 100 kg while those for kinnow are per 100 pieces. For the purpose of analysis the main consumer district for all crops is taken as Lahore, which in 2017 had a population of over 11 million, i.e., 27.5 percent of Punjab's urban population, while five districts with the highest production of the selected crops in the Punjab (for the year 2016-2017) are chosen as the producer districts for that crop[14]. Some limitations of the data are: i) price data is not available for all the selected districts and, ii) price data is available primarily for the months in the harvest period but there are still missing values for some days within the harvest period. The harvest period for purposes of analysis is taken as: basmati rice, September-October; kinnow, January-March; mango, July-August; potatoes, January-February, April-May, August and October; onions, May-June, August and November-December (Pakistan Bureau of Statistics, 2016). Missing values, up to a maximum of two days, have been replaced with an average of the previous two days.

Methodology

The two dimensions of price transmission that will be discussed for each crop are vertical and horizontal (or spatial) price transmission. While discussing vertical transmission, we will try to understand the linkage between the prices in the main consumer market and the largest producer markets (up to a maximum of five) for each crop. For horizontal price transmission, the extent of integration that exists within the producer markets will be discussed. Price changes in the producer markets selected for each crop are analyzed to see whether there is any visible direction of transmission of price signals among the producers. In the discussion, the selected producer markets are considered as clusters if they are spatially close to each other.

[13] Data for mango, rice, potatoes and onions is from 2010-2017, while in the case of kinnow price data for 2014 is unavailable.

[14] If price data is not available for a particular district, the district with the next largest production of that crop in the Punjab is selected. However, for selection of producer districts a minimum 5 percent of Punjab's production of the crop rule is applied, and as a result for some crops there may be fewer than 5 districts included in the analysis.

Each crop is analyzed as follows. We conduct Granger causality tests to see the causality of the relationship that exists between market prices in both horizontal and vertical frameworks. In order to carry out the Granger causality tests, the following steps have to be executed. Each market is checked for its order of integration using the Augmented Dickey-Fuller (ADF) test for each series of prices. ADF tests the null hypothesis that a unit root exists and if this is rejected, the series is said to be stationary (Elliott et al., 1996). In the case that the pair of series (both while examining vertical and horizontal price transmission) are found to be Integrated of order 0, I(0), we conclude that the series are not cointegrated and use a VAR framework to check for size and speed of the price adjustment among markets (Rapsomanikis et al., 2004). We then test for Granger causality within a VAR framework to assess vertical and horizontal price transmission. If the market pairs are integrated at order 1, I(1), they may be cointegrated and several tests are conducted to check for that[15]. Once the cointegration of markets has been determined, the series are tested for Granger causality. If the series are cointegrated, a VECM is usually estimated, and if they are not cointegrated, a VAR model is estimated and then checked for Granger causality. Cointegration itself cannot be used to make conclusions about the direction of causation between prices therefore causality tests are necessary (Ibid, 2004). Since there are missing values in our data, a VECM model could not be estimated. Therefore, only a VAR model is run to estimate the integration among markets.

4. Results

In this section, the discussion of each of the five selected crops is organized as follows: first, we discuss the nature of the crop, i.e., production, shelf life/storage, importance of exports or imports, etc.; second, we analyze the horizontal (spatial) price transmission among producer districts; and finally we look at the vertical price transmission between consumer and the producer markets.

[15]"The Johansen test is used to assess the pair-wise co-integration rank of producer-consumer markets. The cointegrating rank (r) is determined based on acceptance/rejection of null and alternative hypotheses. Next, cointegration is tested using the Two-Way Engle Granger Approach. This involves testing the cointegration of two markets based on the fact that deviations from equilibrium condition of two non-stationary variables should be stationary. This implies that, while price series may wander extensively, pairs should not diverge from one another in the long-run" (Rapsomanikis, 2004, p. 59).

Potato

Potato is an important and expanding vegetable crop in Pakistan with an area and production of 178 thousand hectares and 3,831 thousand tons, respectively, in 2016 (Ministry of National Food Security and Research, 2019). Punjab province is the leading potato producer with a total production of3,660thousand tons (i.e., 96percent of Pakistan's total production) followed by Khyber Pakhtunkhwa at 143 thousand tons, Baluchistan at 22 thousand tons and Sindh at 6 thousand tons (Table 2). Potato has three crops namely autumn (September-February), summer (March-October) and spring (January-May), with the three contributing 70-75 percent, 15-20 percent and 7-10 percent of the total production respectively (Trade Development Authority of Pakistan, 2010). The main potato producing districts in Punjab are Okara, Sahiwal, Kasur, Pakpattan and Chiniot[16] (see Table 2).

Table 2: Potatoes: Area, Production and Share by Major Producer Districts (2016-2017)

District	Area (in 000 hectares)	Production (in 000 tons)	% Share of Punjab's Production
Okara	54.1	1269.7	34.7
Sahiwal	25.0	522.7	14.3
Kasur	19.3	429.2	11.7
Pakpattan	18.6	417.6	11.4
Chiniot	9.4	196.5	5.4
Punjab	166.4	3660.5	100

Sources: Directorate of Agriculture, Crop Reporting Services, 2018 and Ministry of National Food Security & Research, 2019.

In Punjab, potatoes are primarily produced for sale in urban markets and it can be safely stored up to 6 months (Arain, n.d.). The autumn crop, in addition to feeding the instant market, is placed in cold storage. The stored potatoes are gradually released during the lean crop periods generally from June onward. Pakistan is an exporter of potatoes and about 12 percent of the production is exported, with Afghanistan, UAE and Sri Lanka being the main markets (See Table 3).

[16] Chiniot is not included in the analysis because of non-availability of price data.

Table 3: Exports of Potatoes from Pakistan

Annual Average	Partner Country	Quantity (000' tons)	Trade Value (million US $)
2015-2017	Afghanistan	166	50
2015-2017	Sri Lanka	71	12
2015-2017	United Arab Emirates	94	14
2015-2017	World	426	94

Source: UN Comtrade database, 2015-2017.

Horizontal Price Transmission in the Potato Market

To measure horizontal price transmission in the potato market, we look at the relationship between the prices in the producer markets. It is likely that horizontal price transmission occurs through transfer of information rather than actual movement of the product between the producer districts. Three of the four largest producers (Okara, Sahiwal and Pakpattan) are relatively close to each other[17], and this cluster contributes over 60 percent of the total production of potatoes in Punjab. The Granger causality results show that the largest producer, Okara, causes a change in price in the other two producer districts in the cluster, implying horizontal price transmission occurs in this direction (Table 4). The other two districts in the cluster, Sahiwal and Pakpattan, have a bidirectional relationship with each other. As far as Kasur is concerned, Sahiwal and Pakpattan have a unidirectional relationship with it and the two districts cause a change in price in Kasur. However, there doesn't seem to be any horizontal price transmission taking place between Okara and Kasur. But as Kasur is more or less a suburb of Lahore, vertical transmission between the largest producer (Okara) and the main consumer market (Lahore) may be muddling the horizontal relationship between Okara and Kasur.

[17]Okara is at a distance of about 60 km and 40 km from Pakpattan and Sahiwal, respectively, while Pakpattan is about 45 km from Sahiwal.

Table 4: VAR Descriptive Statistics – Potato Granger Causality Tests-Horizontal Transmission

Dependent Variable in Regression

(1)	(2)	(3)	(4)	(5)
Regressor	Okara	Sahiwal	Kasur	Pakpattan
Okara	-	**0.067**	0.349	**0.077**
Sahiwal	0.171	-	**0.000**	**0.000**
Kasur	0.147	0.500	-	0.101
Pakpattan	0.829	**0.000**	**0.000**	-

Source: Author's calculations using AMIS data set 2010-2017.

Note 1: The table shows results from Granger-causality statistics that examine whether lagged values of one variable help to predict another variable. Column 1 shows the regressor while columns 2-5 show the dependent variables. The results were computed from a VAR model with an average of three lags and a constant term over the 2010-2017 sample period.

Note 2: The entries in the columns show the p-values for F-tests. P value is a measure of significance and it is significant at 10% if $\varrho<0.1$.

As far as the speed of adjustment in prices under horizontal transmission is concerned, prices in Pakpattan adjust to prices in Okara within two days while prices in Sahiwal adjust to prices in Okara within four days. The two smaller producers in the cluster (Pakpattan and Sahiwal) are well integrated among themselves as the adjustments take place within a day in both directions. Pakpattan and Sahiwal are also well integrated with Kasur as price adjustments are taking place within a day (see Table 5).

Table 5: Vector Auto Regression Model Results for Price Adjustment in the Potato Market- Horizontal Price Transmission

(1) *Regressor*	*(2)* *Day of Adjustment*	*(3)* *Dependent Variable*			
		Okara	Sahiwal	Kasur	Pakpattan
Okara	1	-	-0.097	0.098[a]	0.208
	2	-	0.147	-	0.344**[b]
	3	-	-0.015	-	-
	4	-	0.436***	-	-
Sahiwal	1	0.009	-	0.196***	0.243***
Pakpattan	1	-0.026	0.178***	-	0.133***
Kasur	1	-0.142	0.063	0.180***	-

Source: Author's calculations using AMIS data set 2010-2017.

[a]**:** For presentation purposes, one lag was selected (according to AIC criteria) for regression of (Okara- Kasur) therefore only day 1 adjustment coefficient is reported.

[b]**:**For presentation purposes, two lags were selected (according to AIC criteria) for regression of (Okara-Pakpattan) therefore only day 1 and day 2 adjustment coefficients are reported.

Note 1: The table shows the results from the Vector autoregressive model. It shows the speed at which the vertical and horizontal price adjustments take place. The results were computed from a VAR model with a minimum of one lag and a constant term over the 2010-2017 sample period. Column 1 shows the regressor, Column 2 shows the day of adjustment and column 3 shows the dependent variables.

Note 2: The entries in the columns show the coefficients. The number of * against each coefficient shows the significance using the p values. That is * representing significance of p value at 10%, ** representing significance of p value at 5% and *** representing significance of p value at 1%.

Vertical Price Transmission in the Potato Market

To examine vertical price transmission in the potato market, we look at the relationship between the prices in the consumer market (Lahore) and the producer markets. Vertical transmission is a result of both a transfer of information and the commodity (potatoes). The price of potatoes in Lahore determines the price in the largest producer market Okara as well as the other producers. While the consumer market drives prices in the largest producer market, there exists a bidirectional relationship between Lahore and the other three producers – Sahiwal, Pakpattan and Kasur, which implies that these producer markets also drive the prices in the consumer market (See Table 6).

Table 6: VAR Descriptive Statistics-Potato Granger Causality Tests-Vertical Transmission

Dependent Variable in Regression

Regressor (1)	(2) Lahore	(3) Okara	(4) Sahiwal	(5) Kasur	(6) Pakpattan
Lahore	-	**0.008**	**0.000**	**0.000**	**0.000**
Okara	0.967				
Sahiwal	**0.003**				
Kasur	**0.028**				
Pakpattan	**0.000**				

Source: Author's calculations using AMIS data set 2010-2017.

Note 1: The table shows results from Granger-causality statistics that examine whether lagged values of one variable help to predict another variable. Column 1 shows the regressor while the columns 2-6 show the dependent variables. The results were computed from a VAR model with an average of two lags and a constant term over the 2010-2017 sample period.

Note 2: The entries in the columns show the p-values for F-tests. P value is a measure of significance and it is significant at 10% if $\varrho<0.1$.

Looking at vertical adjustment of prices, prices in Okara, Sahiwal, Pakpattan and Kasur adjust to prices in Lahore within a day. Even though Sahiwal, Pakpattan and Kasur prices adjust in both directions with Lahore, the adjustment is relatively small, i.e. less than 10 percent. The size of the coefficients implies that 20-30 percent of the adjustment takes place within a day from Lahore to the producer markets (except for Kasur) thereby implying that this channel is dominant in transmitting the price signals (Table 7). In a study conducted in Ethiopia using monthly price data, potato producer markets were adjusting to consumer market prices within 3.5 months and bidirectional causality was also observed (Tadesse, 2016).

Table 7: Vector Auto Regression Model Results for Price Adjustment in the Potato Market- Vertical Price Transmission

(1) *Regressor*	*(2)* *Day of Adjustment*	*(3)* *Dependent Variable*			
Lahore		Okara	Sahiwal	Kasur	Pakpattan
	1	0.213***	0.245***	0.143***	0.303**
		Lahore			
Okara	1	0.059			
Sahiwal	1	0.054**			
Kasur	1	0.084***			
Pakpattan	1	0.074***			

Source: Author's calculations using AMIS data set 2010-2017.
Note 1: The table shows the results from the Vector autoregressive model. It shows the speed at which the vertical and horizontal price adjustments take place. The results were computed from a VAR model with a minimum of one lag and a constant term over the 2010-2017 sample period. Column 1 shows the regressor, Column 2 shows the day of adjustment and column 3 shows the dependent variables.
Note 2: The entries in the columns show the coefficients. The number of * against each coefficient shows the significance using the p values. That is * represents significance of p value at 10%, ** represents significance of p value at 5% and *** represents significance of p value at 1%.

To sum up, it is seen that the potato market is connected both vertically and horizontally. Generally, most adjustment in the prices between markets takes place within a day of the change taking place in the other markets. Therefore, we can say that the potato market in the Punjab is well integrated and adjustments are rapid.

Onion

The total area and production of onions was 340 thousand hectares and 1833 thousand tons, respectively, in 2016 (Ministry of National Food Security and Research, 2019). Sindh province is the leading onion producer with a total production of748thousand tons followed by Baluchistan at 532 thousand tons, Punjab at 370 thousand tons and Khyber Pakhtunkhwa at 184 thousand tons (Table 1). In other words, only 20 percent of onions are produced in the Punjab, and since it has over 50 percent of Pakistan's population, probably a major part of the onions sold in its consumer markets, such as Lahore, comes from Sindh

and Baluchistan, which produce 40 and 30 percent, respectively, of the country's output. The main onion producing districts in Punjab are Khanewal, Rajanpur, Rahim Yar Khan and Bahawalpur[18] (Table 8).

Table 8: Onions: Area, Production and Share by Major Producer Districts (2016-2017)

District	Area (in 000 hectares)	Production (in 000 tons)	% Share of Punjab's Production
Khanewal	6.4	50.1	13.5
Rajanpur	1.7	35.5	9.6
Rahim Yar Khan	3.1	34.6	9.3
Bahawalpur	3.0	24.2	6.5
Punjab	42.8	370.4	100.0

Sources: Directorate of Agriculture, Crop Reporting Services, 2018 and Ministry of National Food Security & Research, 2019.

The agro-ecological diversity in the country enables onions to be produced almost year-round. Due to limited shelf life and absence of cold storage facilities in the country, onions cannot be kept for an extended period of time and have to be sold in the domestic or international markets soon after the time of harvest (Agriculture Market Information Service, 2004). Therefore, Pakistan both exports and imports onions each year, with the two quantities being about the same, i.e., equivalent to about 6 percent of its production. Exports are primarily to UAE, Malaysia and Afghanistan while imports are almost entirely from Afghanistan and China (See Table 9). Imports from Afghanistan probably largely supply Khyber Pakhtunkhwa and the northern /central districts of Punjab, including Lahore.

[18] No other district in the Punjab produces as much as 5 percent of Punjab's output therefore only 4 producer districts are included in the horizontal (spatial) price transmission analysis.

Table 9: Export of Onions from Pakistan

Annual Average	Partner Country	Quantity (000' tons)	Trade Value (million US $)
2015-2017	United Arab Emirates	34	6.3
2015-2017	Afghanistan	13	5
2015-2017	Malaysia	33	7.2
2015-2017	World	121	27.5
	Import of Onions from Pakistan		
2015-2017	Afghanistan	77	13.7
2015-2017	China	38	70.8
2015-2017	World	118	87.3

Source: UN Comtrade database, 2015-2017.

Horizontal Price Transmission in the Onion Market

To measure horizontal price transmission in the onion market, we look at the relationship between the prices in the producer markets. The selected producer districts. i.e., Khanewal, Rajanpur, Rahim Yar Khan, Bahawalpur and Lodhran are all in southern Punjab and lie along the road links from Sindh/Baluchistan to Lahore. The Granger causality results show a bidirectional relation between all producers. This shows that horizontal price transmission occurs well across all the producer districts, implying that each producer causes a change in price in the other producer within the southern Punjab cluster (see Table 10).

Table 10: VAR Descriptive Statistics- Onion Granger Causality Tests-Horizontal Price Transmission

Dependent Variable in Regression

Regressor (1)	(2) Khanewal	(3) Rajanpur	(4) Rahim Yar Khan	(5) Bahawalpur
Khanewal	**-**	**0**	**0.002**	**0**
Rajanpur	**0**	**-**	**0**	0.627
Rahim Yar Khan	**0**	**0.006**	**-**	**0**
Bahawalpur	**0**	**0**	**0.011**	**-**

Source: Author's calculations using AMIS data set 2010-2017.

Note 1: The table shows results from Granger-causality statistics that examine whether lagged values of one variable help to predict another variable. Column 1 shows the regressor while the remaining (2-6) show the dependent variables. The results were computed from a VAR model with an average of three lags and a constant term over the 2010-2017 sample period.

Note 2: The entries in the columns show the p-values for F-tests. P value is a measure of significance and it is significant at 10% if $\rho<0.1$.

As far as the adjustment period in prices under horizontal transmission is concerned, one-day adjustments are found among all markets. This implies that markets are well integrated, as rapid transmission of price information among all producer markets is found. Khanewal being the largest producer also efficiently adjusts to prices of other smaller producers and vice versa (see Table 11).

Table 11: Vector Auto Regression Model Results for Price Adjustment in the Onion Market- Horizontal Price Transmission

(1) Regressor	*(2) Day of Adjustment*	*(3) Dependent Variable*			
		Khanewal	RajanPur	Rahim Yar Khan	Bahawalpur
Khanewal	1	-	0.185***	0.185***	0.166***
RajanPur	1	0.279***	-	0.229***	0.261***
Rahim Yar Khan	1	0.406***	0.129**	-	0.190***
Bahawalpur	1	0.279***	0.044	0.119*	-

Source: Author's calculations using AMIS data set 2010-2017.
Note 1: The table shows the results from the Vector autoregressive model. It shows the speed at which the vertical and horizontal price adjustments take place. The results were computed from a VAR model with a minimum of one lag and a constant term over the 2010-2017 sample period. Column 1 shows the regressor, Column 2 shows the day of adjustment and column 3 shows the dependent variables.
Note 2: The entries in the columns show the coefficients. The number of * against each coefficient shows the significance using the p values. That is * represents significance of p value at 10%, ** represents significance of p value at 5% and *** represents significance of p value at 1%.

Vertical Price Transmission in the Onion Market

To examine vertical price transmission in the onion market, we look at the relationship between the prices in the consumer market (Lahore) and the producer markets. Vertical transmission is a result of both a transfer of information and the commodity (onion). The results show that the price of onions in Lahore determines the price in all producer markets and, at the same time, all producers (except Bahawalpur) determine the price in the Lahore. This means all producers are well connected with the consumer market and vice versa (see Table 12).

Table 12: VAR Descriptive Statistics- Onion Granger Causality Tests- Vertical Price Transmission

Dependent Variable in Regression

Regressor (1)	(2) Lahore	(3) Khanewal	(4) RajanPur	(5) Rahim Yar Khan	(6) Bahawalpur
Lahore	-	**0.011**	**0.000**	**0.000**	**0.000**
Khanewal	**0.000**				
RajanPur	**0.000**				
Rahim Yar Khan	**0.000**				
Bahawalpur	0.166				

Source: Author's calculations using AMIS data set 2010-2017.

Note 1: The table shows results from Granger-causality statistics that examine whether lagged values of one variable help to predict another variable. Column 1 shows the regressor while the remaining (2-7) show the dependent variables. The results were computed from a VAR model with an average of three lags and a constant term over the 2010-2017 sample period.

Note 2: The entries in the columns show the p-values for F-tests. P value is a measure of significance and it is significant at 10% if $\rho<0.1$.

The onion market is well connected as adjustment in the prices among markets takes place within a day of the change that takes place in price. The onion market is therefore is well integrated and adjustments are rapid. Within a day, the price in Lahore (the consumer market) adjusts to prices in a producer market and vice versa. However, the size of the coefficient in most districts (with exception of Rahim Yar Khan and Bahawalpur) shows a larger effect (of 50-70 percent of the adjustment) in the direction of producer markets impacting the consumer market. This implies a supply driven effect showing that the price is set in the producer market and that in turn determines the price in the consumer market the next day (See Table 13).

Table 13: Vector Auto Regression Model Results for Price Adjustment in the Onion Market- Vertical Price Transmission

(1) Regressor	*(2) Day of Adjustment*	*(3) Dependent Variable*			
		Khanewal	Rajanpur	Rahim Yar Khan	Bahawalpur
Lahore	1	0.064**	0.044**	0.303***	0.296***
		Lahore			
Khanewal	1	0.549***			
RajanPur	1	0.705***			
Rahim Yar Khan	1	0.166***			
Bahawalpur	1	-0.03			
Bahawalpur	2	0.142**			

Source: Author's calculations using AMIS data set 2010-2017.
Note 1: The table shows the results from the Vector autoregressive model. It shows the speed at which the vertical and horizontal price adjustments take place. The results were computed from a VAR model with a minimum of one lag and a constant term over the 2010-2017 sample period. Column 1 shows the regressor, Column 2 shows the day of adjustment and column 3 shows the dependent variables.
Note 2: The entries in the columns show the coefficients. The number of * against each coefficient shows the significance using the p values. That is * represents significance of p value at 10%, ** represents significance of p value at 5% and *** represents significance of p value at 1%.

To sum up, it is seen that the onion market is also well connected both vertically and horizontally. Generally, most adjustment in the prices between markets takes place within a day of the change taking place in the other markets. Therefore, we can say that the onion market in the Punjab is well integrated and adjustments are rapid.

Mango

The total area and production of mangos was 419 thousand hectares and 1784 thousand tons, respectively, in 2016 (Ministry of National Food Security and Research, 2019). Mango is the second largest fruit produced in Pakistan after citrus. Punjab produces 77 percent of Pakistan's total mango output, while the rest is largely produced in Sindh (Table 2). More than 200 varieties of mangoes are cultivated in Pakistan. Sindhri (primarily in Sindh) and Chaunsa (primarily in the Punjab) are the most famous varieties in the country (Javed et.al, 2012). Because of its

dominance among the varieties in the Punjab and the non-availability of data for other varieties our analysis is based on the Chaunsa variety. The main mango producing districts in Punjab are Multan, Rahim Yar Khan, Khanewal and Muzaffargarh[19]. Area, production and percentage of Punjab's output produced in each district can be seen in Table 14.

Table 14: Mango: Area, Production and Share by Major Producer Districts (2016-2017)

District	Area (in 000 hectares)	Production (in 000 tons)	% share of Punjab's Production
Multan	31	420	31
Rahim Yar Khan	24	310	23
Khanewal	14	180	13
Muzaffargarh	19	269	7
Punjab	106	1,375	100

Sources: Directorate of Agriculture, Crop Reporting Services, 2018 and Ministry of National Food Security & Research, 2019.

Mangoes have a extremely short shelf life, which is measured in days rather than in weeks and this has implications for the direction of vertical price transmission. Also, as mangoes are highly perishable, they are exported by air (Baloch et.al, 2011). Pakistan has a very weak system for managing the cool chain for effective transportation of fresh mangoes from producers to the airports as well for meeting the international phytosanitary standards for export of fresh fruits and therefore less than 5 percent of the mango crop is exported. Pakistan mainly exports mangoes to United Arab Emirates, United Kingdom and Saudi Arabia (See Table 15).

[19] As price data is not available for Muzaffargarh, it is not included in the analysis. Also as no other district in the Punjab produces as much as 5 percent of Punjab's output, only 3 producer districts are included in the horizontal (spatial) price transmission analysis.

Table 15: Exports of Mango Crop from Pakistan

Annual Average	Partner Country	Quantity (000' tonnes)	Trade Value (US $)
2015-2017	United Arab Emirates	26	19.3
2015-2017	United Kingdom	7	9.9
2015-2017	Saudi Arabia	4	5.1
2015-2017	World	54	51.0

Source: UN Comtrade database, 2015-2017.

Horizontal Price Transmission in the Mango Market

To measure horizontal price transmission in the mango market, we look at the relationship between the prices in the producer markets. Horizontal transmission occurs by means of a transfer of information. In the mango market, the large producers are all in southern Punjab with two of them being fairly close to each other (Multan and Khanewal), together contributing 44 percent of total production in Punjab. The largest producer Multan causes a change in the price of Rahim Yar Khan whereas Khanewal causes a change in price in Multan. Khanewal and Rahim Yar Khan Granger-cause changes in price within their markets, implying a bi-directional relationship (see Table 16).

Table 16: VAR Descriptive Statistics – MangoGranger Causality Tests-Horizontal Transmission

Dependent Variable in Regression

(1) *Regressor*	(2) Multan	(3) Rahim Yar Khan	(4) Khanewal
Multan	-	**0.030**	0.505
Rahim Yar Khan	0.227	-	**0.002**
Khanewal	**0.084**	**0.000**	-

Source: Author's calculations using AMIS data set 2010-2017.

Note 1: The table shows results from Granger-causality statistics that examine whether lagged values of one variable help to predict another variable. Column 1 shows the regressor while the remaining (2-4) show the dependent variables. The results were computed from a VAR model with an average of three lags and a constant term over the 2010-2017-sample period.

Note 2: The entries in the columns show the p-values for F-tests. P value is a measure of significance and it is significant at 10% if $\rho<0.1$.

As far as the time period of adjustment in prices under horizontal transmission is concerned, prices in Rahim Yar Khan adjust to prices in Multan within 3 days while Khanewal causes a change in price in Multan within 2 days. Khanewal and Rahim Yar Khan both adjust to each other's prices. However, the mechanism is such that Multan causes a change in price in Rahim Yar Khan, and Khanewal causes a change in price in both Multan and Rahim Yar Khan (See Table 17). Despite being a smaller producer, Khanewal plays a more central role in horizontal transmission of prices. A possible explanation maybe that Khanewal, as one of new settlements at time when the British developed the canal colonies in the Punjab, has always been agriculturally the most progressive district in Southern Punjab and probably seen as the trend-setter by other districts in the region.

Table 17: Vector Auto Regression Model Results for Price Adjustment in the Mango Market- Horizontal Price Transmission

(1)	*(2)*	*(3)*		
Regressor	*Day of Adjustment*	*Dependent Variable*		
		Multan	Rahim Yar Khan	Khanewal
Multan	1	-	-0.027	0.087
	2	-	0.112	0.075
	3	-	0.210**	-
Rahim Yar Khan	1	0.034	-	-0.038
	2	-0.008	-	0.0699
	3	0.006	-	0.107*
Khanewal	1	-0.043	0.104*	-
	2	0.063**	-0.053	-

Source: Author's calculations using AMIS data set 2010-2017.

Note 1: The table shows the results from the Vector autoregressive model. It shows the speed at which the vertical and horizontal price adjustments take place. The results were computed from a VAR model with a minimum of one lag and a constant term over the 2010-2017. Column 1 shows the regressor, Column 2 shows the day of adjustment and column 3 shows the dependent variables.

Note 2: The entries in the columns show the coefficients. The number of * against each coefficient shows the significance using the p values. That is * represents significance of p value at 10%, ** represents significance of p value at 5% and *** represents significance of p value at 1%.

Vertical Price Transmission in the Mango Market

To examine vertical price transmission in the mango market, we look at the relationship between the prices in the consumer market (Lahore) and the producer markets. Vertical transmission is a result of both a transfer of information and the commodity (mango). Granger causality tests help shows a unidirectional relationship between Lahore and Multan where the price of mangoes in Lahore determines the price in the largest producer market, Multan. The fixed supply of mangoes at any time and their short-shelf life means that the largest producer (Multan) has to be the price taker. Khanewal being virtually a suburb of Multan, which is also a big city, has the option to ship the mangoes either to Lahore or Multan. Thus, the decision by Khanewal producers whether to sell in Lahore or Multan has an impact on the prices in the former.As a result, in the case of Khanewal, the direction of the price signal seems to be from the producer to the consumer market[20]. The relationship between Lahore and Rahim Yar Khan (which is the 2nd largest producer in the Punjab) is bidirectional. The reason for this maybe that the distance between Lahore and Rahim Yar Khan is almost 600 km, i.e., about the same as its distance from Karachi (population over 15 million) in Sindh and therefore producers in Rahim Yar Khan could choose whether to send mangoes to Lahore or Karachi based on the prices in the two cities and their decision in turn would impact on the prices of mangoes in the two cities (See Table 18).

[20] It is also likely that, as discussed for horizontal transmission, Khanewal's position as a price setter for Lahore is because of its central role in Southern Punjab.

Table 18: VAR Descriptive Statistics- MangoGranger Causality Tests- Vertical Price Transmission

Dependent Variable in Regression

(1)	(2)	(3)	(4)	(5)
Regressor	**Lahore**	**Multan**	**Rahim Yar Khan**	**Khanewal**
Lahore		**0.036**	**0.016**	0.488
Multan	**0.104**			
Rahim Yar Khan	**0.001**			
Khanewal	**0.012**			

Source: Author's calculations using AMIS data set 2010-2017.

Note 1: The table shows results from Granger-causality statistics that examine whether lagged values of one variable help to predict another variable. Column 1 shows the regressor while the remaining (2-5) show the dependent variables. The results were computed from a VAR model with an average of three lags and a constant term over the 2010-2017 sample period.

Note 2: The entries in the columns show the p-values for F-tests. P value is a measure of significance and it is significant at 10% if $\rho<0.1$.

When looking at adjustment of prices between consumer and producer markets, prices in Lahore determine prices in Multan and vice versa, after three days. However, the size of the coefficient shows that the dominant transmission channel is also an adjustment in prices from the producer to the consumer market. The relationship between Lahore and Rahim Yar Khan is significant in both directions within 5 days; however, the size of coefficient shows that the dominant transmission channel is an adjustment in prices from the consumer to the producer market. Khanewal, on the other hand, has the most rapid adjustment mechanism and prices in Lahore adjust to prices in Khanewal within a day (see Table 19). In India, mango markets are found to be well integrated where adjustments take place within a month of the change that takes place in prices (Pardhi, 2016).

Table 19: Vector Auto Regression Model Results for Price Adjustment in the Mango Market- Vertical Price Transmission

(1)	*(2)*	*(3)*		
Regressor	*Day of Adjustment*	*Dependent Variable*		
Lahore		Multan	Rahim Yar Khan	Khanewal
	1	-0.044	0.054	0.097
	2	-0.067	0.054	0.012
	3	0.087*	-0.014	-0.061
	4	0.04	-0.124	0.006
	5		0.117*	-0.0001
		Lahore		
Multan	1	0.075		
	2	0.053		
	3	0.173**		
Rahim Yar Khan	1	0.767		
	2	0.005		
	3	0.007		
	4	-0.052		
	5	0.093**		
Khanewal	1	0.010**		

Source: Author's calculations using AMIS data set 2010-2017.
Note 1: The table shows the results from the Vector autoregressive model. It shows the speed at which the vertical and horizontal price adjustments take place. The results were computed from a VAR model with a minimum of one lag and a constant term over the 2010-2017 sample period. Column 1 shows the regressor, Column 2 shows the day of adjustment and column 3 shows the dependent variables.
Note 2: The entries in the columns show the coefficients. The number of * against each coefficient shows the significance using the p values. The * represents significance of p value at 10%, ** represents significance of p value at 5% and *** represents significance of p value at 1%.

Kinnow

Kinnow (mandarin) is one of the most important fruit crops in Pakistan with a total area and production of 206 thousand hectares and 2180 thousand tons, respectively, in 2016 (Ministry of National Food Security and Research, 2019). Citrus is almost entirely grown in the Punjab with 97 percent of total production occurring in this province (Table 2). The peak kinnow harvesting months are January to March. The main kinnow producing districts in Punjab are Sargodha, Toba Tek

Singh[21], Mandi Bahauddin, and Khanewal. Area, production and percentage produced in each district can be seen in Table 20.

Table 20: Kinnow: Area, Production and Share by Major Producer Districts (2016-2017)

District	Area (in 000 hectares)	Production (in 000 tons)	% Share of Punjab's Production
Sargodha	83	1,077	56
Toba Tek Singh	12	215	11
Mandi Bahauddin	9	116	6
Punjab	**150**	**1917**	**100**

Sources: Directorate of Agriculture, Crop Reporting Services, 2018 and Ministry of National Food Security & Research, 2019.

Being a non-climacteric fruit, kinnow without treatment has a low shelf life even in cold storage and may lose its quality because of some physiochemical changes (Haider et. al, 2017). In the 1990s, the adoption of a new technology, imported from Italy, for waxing of kinnow upon harvesting greatly extended its shelf-like and that initiated the era of kinnow exports for Pakistan. Currently, over 20 percent of the production is exported with main markets Afghanistan (and possibly onward to other Central Asian Countries), the Russian Federation and United Arab Emirates (see Table 21).

Table 21: Exports of Kinnow Crop from Pakistan

Annual Average	Partner	Quantity (000' tons)	Trade Value (US $)
2015-2017	Afghanistan	162	62
2015-2017	Russian Federation	85	45
2015-2017	United Arab Emirates	46	17
2015-2017	World	389	165

Source: UN Comtrade database, 2015-2017.

[21] As price data is not available for Toba Tek Singh and Mandi Bahauddin, they could not be included in the analysis. Thus, as no other district in the Punjab produces as much as 5 percent of Punjab's output, we only one producer district, i.e. Sargodha, and therefore no horizontal (spatial) price transmission analysis is carried out.

Vertical Price Transmission in the Kinnow Market

To examine vertical price transmission in the kinnow market, we look at the relationship between the prices in the consumer market (Lahore) and the producer market (Sargodha). Vertical transmission is a result of both a transfer of information and the commodity (kinnow). The Granger causality test shows a unidirectional relationship between producer and consumer market. The price of kinnow in Lahore determines the price of Kinnow in Sargodha. The opposite channel is also significant at around 10 percent significance level implying that there is bi-directional relationship (see Table 22).

Table 22: VAR Descriptive Statistics- Kinnow Granger Causality Tests- Vertical Transmission

Dependent Variable in Regression

(1)	**(2)**	**(3)**
Regressor	**Lahore**	**Sargodha**
Lahore	-	**0.005**
Sargodha	0.101	-

Source: Author's calculations using AMIS data set 2010-2017 (excluding 2014).
Note 1: The table shows results from Granger-causality statistics that examine whether lagged values of one variable help to predict another variable. Column 1 shows the regressor while the remaining (2-5) show the dependent variables. The results were computed from a VAR model with an average of three lags and a constant term over the 2010-2017 (excluding 2014) sample period.
Note 2: The entries in the columns show the p-values for F-tests. P value is a measure of significance and it is significant at 10% if $\rho<0.1$.

We measured the speed of adjustment of prices between markets as three days. But the size of the coefficient shows that the adjustment of prices from the producer, Sargodha, to Lahore dominates, i.e. Sargodha is the price setter (see Table 23). The reason for this may be that the price in Sargodha is determined by demand and prices in the export markets. Also as kinnow's shelf-life is significantly extended by processing and storage, the sellers are not in a hurry to sell in the local market because the sellers know that any kinnows in storage that they are unable to export can always be sold in the local market in the off-season at a premium.

Table 23: Vector Auto Regression Model Results for Price Adjustment in the Kinnow Market- Vertical Price Transmission

(1)	*(2)*	*(3)*
Regressor	*Day of Adjustment*	*Dependent Variable*
		Sargodha
Lahore	1	-0.002
	2	-0.018
	3	0.03*
		Lahore
Sargodha	1	0.113
	2	0.369
	3	0.532**

Source: Author's calculations using AMIS data set 2010-2017 (excluding 2014).
Note 1: The table shows the results from the Vector autoregressive model. It shows the speed at which the vertical and horizontal price adjustments take place. The results were computed from a VAR model with a minimum of one lag and a constant term over the 2010-2017 (excluding 2014) sample period. Column 1 shows the regressor, Column 2 shows the day of adjustment and column 3 shows the dependent variables.
Note 2: The entries in the columns show the coefficients. The number of * against each coefficient shows the significance using the p values. A * represents significance of p value at 10%, ** represent significance of p value at 5% and *** represent significance of p value at 1%.

Rice

The total area and production of rice was 4291 thousand hectares and 6849 thousand tons, respectively, in 2016 (Ministry of National Food Security and Research, 2019). Rice is grown primarily in Sindh and Punjab, with 64 percent being produced in the latter. Basmati rice is the most famous of the rice varieties grown in Pakistan and is known for its flavor and quality (Gain Report- USDA Foreign Agriculture Service, 2018). Basmati rice is harvested from September to October and Punjab produces over 90 percent of the basmati rice grown in Pakistan (Table 2). The main rice producing districts in Punjab are Sheikhupura, Hafizabad, Sialkot, Nankana Sahab, Gujranwala and Okara[22]. Area, production and percentage produced in each district can be seen in Table 24.

[22] Due to non-availability of price data for Sheikhupura, Hafizabad, and, Nankana Sahab, the only markets that could be considered for this analysis are Sialkot, Gujranwala, and Okara.

Table 24: Basmati Rice: Area, Production and Share by Major Producer Districts (2016-2017)

District	Area (in 000 hectares)	Production (in 000 tons)	% Share of Total Production
Sheikhupura	158	290	11.5
Hafizabad	104	213	8.4
Sialkot	115	206	8.2
Nankana Sahab	99	194	7.7
Gujranwala	102	184	7.3
Okara	72	143	5.6
Punjab	**1353**	**2524**	**100**

Sources: Directorate of Agriculture, Crop Reporting Services, 2018 and Ministry of National Food Security & Research, 2019.

Pakistan is among top ten rice producers in the world and it exports just under 60 percent of its rice production. Basmati rice as a percentage of total rice exports from Pakistan is about 26 percent by value and about 13 percent by quantity (Rice Exporters Association of Pakistan, 2015-2017, see table 25). Farmers harvest paddy, which can only be kept for short period unless it is dried in a mill. Rice millers acquire most of the crop, dry and polish it, and then store it. Once milled, rice can be stored for more than a year. Rice millers are also the primary exporters of rice, with some of the large exporters owning many rice mills spread over the main rice growing areas. These large rice exporters also directly market basmati rice domestically under their own brand names. Most of the IRRI rice and some of the basmati rice sold in the domestic market is unbranded.

Table 25: Export of Basmati Rice as a percentage of Total Rice in Pakistan

	Basmati Rice		Total Rice		Basmati Rice percentage share of Total Rice	
	Quantity (000' tons)	Trade Value (million US$)	Quantity (000' tons)	Trade Value (million US $)	Quantity	Trade Value
2015	503	455	4,262	1,860	11.8	24.5
2016	480	427	3,585	1,607	13.4	26.5
2017	501	525	4,024	2,000	12.5	26.2
Average	495	469	3957	1,823	12.6	25.7

Source: Calculations based on data from the Rice Exporters Association of Pakistan, Retrieved 10 January, 2020 from http://reap.com.pk/download/index.asp

The most important export markets for Pakistan's rice are Kenya, Afghanistan, China and United Arab Emirates (see Table 26).

Table 26: Exports of Rice Crop from Pakistan

Annual Average	Partner	Quantity (000' tons)	Trade Value (million US $)
2015-2017	Kenya	533	209
2015-2017	United Arab Emirates	204	150
2015-2017	China	456	161
2016-2017	Afghanistan	1,298	122
2015-2017	World	3,890	1,791

Source: UN Comtrade database, 2015-2017.

Horizontal Price Transmission in the Rice Market

To measure horizontal price transmission in the rice market, we look at the relationship between the prices in the producer markets. Surprisingly, we find no causality in any market, in any direction. This implies that the signals are not being transferred and it can be said that the price transmission mechanism is weak (see Table 27). In the basmati rice market, there are five producers together in a cluster in central Punjab (i.e., Sheikhupura, Hafizabad, Sialkot, Nankana Sahab and Gujranwala) and together they contribute 43 percent of total production

in Punjab. Unfortunately, we have price data from only for two producers in the cluster, which does not include the top two producers, and that limits the usefulness of the analysis. But finding no connectedness between Sialkot and Gujranwala certainly indicates that horizontal price transmission is weak at best. The probable explanation is in the nature of the rice crop and market. A few rice millers in each district control the market in their area and there is a lack of price competition in the market. Also, the rice traded in the producer wholesale markets is a small proportion of total production and is largely for local consumption. Thus, we can conclude that the rice market in Punjab is fragmented and not well integrated.

Table 27: VAR Descriptive Statistics- Rice Granger Causality Tests- Horizontal Transmission

Dependent Variable in Regression

Regressor (1)	**(2) Sialkot**	**(3) Gujranwala**	**(4) Okara**
Sialkot	-	0.257	0.201
Gujranwala	0.51	-	0.888
Okara	0.516	0.663	-

Source: Author's calculations using AMIS data set 2010-2017.

Note 1: The table shows results from Granger-causality statistics that examine whether lagged values of one variable help to predict another variable. Column 1 shows the regressor while the remaining (2-4) show the dependent variables. The results were computed from a VAR model with an average of three lags and a constant term over the 2010-2017-sample period.

Note 2: The entries in the columns show the p-values for F-tests. P value is a measure of significance and it is significant at 10% if $\varrho<0.1$.

As far as the period of adjustment in prices under horizontal transmission is concerned, no adjustment of prices takes place either within the market cluster or with Okara, reinforcing the finding that the producer districts are not integrated with each other (See Table 28).

Table 28: Vector Auto Regression Model Results for Price Adjustment in the Rice Market- Horizontal Price Transmission

Regressor	*(2)*	*(3)*		
(1)	*Day of Adjustment*	*Dependent Variable*		
		Sialkot	Gujranwala	Okara
Sialkot	1	-	0.073	-0.022
Gujranwala	1	0.062	-	0.021
Okara	1	0.082	0.07	-

Source: Author's calculations using AMIS data set 2010-2017 (excluding 2014).

Note 1: The table shows the results from the Vector autoregressive model. It shows the speed at which the vertical and horizontal price adjustments take place. The results were computed from a VAR model with a minimum of one lag and a constant term over the 2010-2017 sample period. Column 1 shows the regressor, Column 2 shows the day of adjustment and column 3 shows the dependent variables.

Note 2: The entries in the columns show the coefficients. The number of * against each coefficient shows the significance using the p values. A * represents significance of p value at 10%, ** represent significance of p value at 5% and *** represent significance of p value at 1%.

Vertical Price Transmission in the Rice Market

To examine vertical price transmission in the rice market, we look at the relationship between the prices in the consumer market (Lahore) and the producer markets. Prices in the two producer districts, Sialkot and Gujranwala, Granger-cause changes in price in the consumer market, thereby implying a supply driven effect from producers to consumers (see Table 29).

Table 29: VAR Descriptive Statistics-Rice Granger Causality Tests-Vertical Price Transmission

Dependent Variable in Regression

(1) *Regressor*	(2) Lahore	(3) Sialkot	(4) Gujranwala	(5) Okara
Lahore	-	0.477	0.771	0.498
Sialkot	**0.000**			
Gujranwala	**0.006**			
Okara	0.107			

Source: Author's calculations using AMIS data set 2010-2017.

Note 1: The table shows results from Granger causality statistics that examine whether lagged values of one variable help to predict another variable. Column 1 shows the regressor while the remaining (2-5) show the dependent variables. The results were computed from a VAR model with an average of three lags and a constant term over the 2010-2017 sample period.

Note 2: The entries in the columns show the p-values for F-tests. P value is a measure of significance and it is significant at 10% if $\rho<0.1$.

The rice market is vertically well connected as the adjustment of prices from Gujranwala and Sialkot to Lahore takes place in one day (see Table 30). This, unlike the findings with regards to horizontal transmission, corresponds to the findings for Bangladesh by Dawson and Dey (2002) that the law of one price holds in the rice market in that country since the rice prices in Dhaka and each regional market were so perfectly integrated with each other that a change in price in one market was mirrored somewhere else.

Table 30: Vector Auto Regression Model Results for Price Adjustment in the Rice Market- Vertical Price Transmission

(1)	*(2)*	*(3)*		
Regressor	***Day of Adjustment***	***Dependent Variable***		
		Sialkot	Gujranwala	Okara
Lahore	1	0.083	0.033	-0.038
		Lahore		
Sialkot	1	0.171***		
Gujranwala	1	0.144**		
Okara	1	0.108		

Source: Author's calculations using AMIS data set 2010-2017 (excluding 2014).
Note 1: The table shows the results from the Vector autoregressive model. It shows the speed at which the vertical and horizontal price adjustments take place. The results were computed from a VAR model with a minimum of one lag and a constant term over the 2010-2017. Column 1 shows the regressor, Column 2 shows the day of adjustment and column 3 shows the dependent variables.
Note 2: The entries in the columns show the coefficients. The * against each coefficient shows the significance using the p values. * represents significance of p value at 10%, ** represents significance of p value at 5% and *** represents significance of p value at 1%.

Summary of Findings

We have found that potato, onion and mango markets are well integrated both horizontally and vertically, with the speed of adjustment generally (with the exception of mango) being very rapid (see Table 31). Therefore, we can say that these three markets are *technically efficient*. However, based on the results it is difficult to say whether kinnow and basmati rice markets are technically efficient. The reasons for this are two-fold.

One, in the case of both the crops a large part of the output is exported and, therefore, it is likely that international prices of these crops play a major role in determining the local price. But since we do not have data on the daily international prices of these crops we are unable to examine the extent of their integration with the world market. However, as there are no government restrictions on their export, we expect that the local producer markets are probably well integrated with the world and regional markets.

Two, for both the crops there are limitations with regards to availability of price data for the producer markets. In the case of kinnow,

we have data for only one producer market and, therefore, it is not possible to examine extent of horizontal integration. In the case of basmati rice we do not have price data for the two largest producer markets. Therefore, the result that the basmati rice market is not integrated horizontally and price signals are not transmitted among producer markets is subject to the caveat that for other crops, the larger producer markets generally play a central role in horizontal transmission, and data on these is missing in the case of rice.

As far as vertical integration is concerned, both markets seem to be fairly well integrated. Therefore, it is likely that the markets for these two crops are also technically efficient, but we cannot categorically say so based on our data. With regards to efficiency of the markets, an interesting finding is that in 40 out of the 44 relationships that have significant causality[23], the adjustment in prices takes place within one day. This rapid adjustment is probably because of widespread use of mobile phones and the resulting real-time communication of price information from one market to another. In other words, the introduction of new communication technologies in the last two decades has probably played an important role in improving the technical efficiency of agricultural markets in the Punjab, and possibly other developing countries.

[23] There are 33 market-pairs for horizontal and vertical transmission combined. As we are looking at adjustment in both directions we have a total of 66 possible results. In the case of Basmati Rice for horizontal transmission we find no significant relationship among the 3 market pairs. Out of the remaining 30 market pairs, in 16 the relationship is unidirectional and in 14 it is bidirectional, i.e. a total of 44 relationships with significant causality.

Table 31: Summary of Results

Crop	Horizontal Transmission				
	Degree of Integration (as indicated by)		Degree of Adjustment (as indicated by)		If Any Market Plays A Central Role
	Direction*	% of markets connected**	Speed of Adjustment+	Coefficient of Adjustment++	
Potato	Unidirectional	Medium	Rapid	Medium	Okara
Onion	Bidirectional	Strong	Rapid	Medium	Khanewal
Mango	Bidirectional	Strong	Medium	Weak	Khanewal
Rice	N.A.	N.A.	N.A.	N.A.	N.A.
	Vertical Transmission				
Crop	**Degree of Integration** (as indicated by)		**Degree of Adjustment** (as indicated by)		**Market(s) Playing a Central or Dominating Role**
	Direction*	**% of markets connected****	**Speed of Adjustment+**	**Coefficient of Adjustment++**	
Potato	Bidirectional	Strong	Rapid	Medium	Consumer (Lahore)
Onion	Bidirectional	Strong	Rapid	Strong	Producers
Mango	Bidirectional	Strong	Slow	Weak	Producers
Kinnow	Unidirectional	N.A.	Medium	Weak	Producer (Sargodha)
Rice	Unidirectional	Weak	Rapid	Medium	Producers

*Direction is explained through granger causality tests. If p value is significant in both directions, we say it is bidirectional and if it is significant in one direction we say it is unidirectional.

**This is determined by looking at what percentage of the total market-pairs in granger causality tests are significant. If % <40% then Weak, if 40% to 60% then Medium, and if >60% then Strong

+ If the significant adjustment coefficient is 1 day then Rapid, if 2-3 days then Medium, and if 4 days then Slow

++ This is determined by looking at the coefficient of the VAR model. Only day 1 significant coefficient sizes are compared. If the significance occurs on a day later than day 1, it is considered as a weak. If the size of the coefficients (i.e. % of price adjustment taking place on day one) for at least 50% of the sample is <10%, then weak, if 10-20% then Medium, and if >20% then Strong.

Another finding of our analysis is that in most cases (potato being the exception) it is the producer markets that determine the price in the consumer market. This is not surprising, because in the case of agricultural products, in the very short run, we can expect market prices to be supply driven. What is interesting is that this is not the case for potatoes, where the price in the producer markets is determined by the consumer market.

The explanation probably lies in the nature of the different crops: In the case of onions and mangoes, because of the short shelf-life, the fact that producer markets determine the price in the consumer markets is not a

reflection of producers' market-power, but the result of the harvest size more or less simultaneously determining prices in both producer and consumer markets. In the case of kinnow and basmati rice, because of the longer shelf-life and the outside option of the export market, it is an indicator of the producers' market-power as the sellers probably decide how much to sell in the local market on any given day, based on the international prices and projected demand. Finally, potatoes are somewhere in-between in the sense that because of the use of cold-storage they have a longer shelf-life but storage is costly and export options are few, therefore, while producers have some market power but it is limited – i.e. daily prices in the producer markets are responsive to prices in the consumer market.

5. A Reality Check

As a test of the medium-term impact of technical efficiency of agriculture markets in Pakistan we look at changes in cropping patterns to see if these are in line with the changes in market demand and government price interventions. An important determinant of demand for agricultural products in a country is income levels and distribution: according to the World Bank (2016) "[i]n Pakistan, the reduction in poverty led to an increase in dietary diversity for all income groups. For the poorest, the share of expenditure devoted to milk and milk products, chicken, eggs and fish rose, as did the share devoted to vegetables and fruits. In contrast, the share of cereals and pulses, which provide the cheapest calories, declined steadily between FY02 and FY14".[24] Thus, if markets are efficient in transmitting price signals, the changing pattern of demand should impact cropping patterns in the medium term.[25].

Trends in cropping patterns for the period 2000 to 2014 are presented in Table 32. It is seen that the share of the area under vegetables and fruits increased by over 30 percent during this period, while that of pulses declined by over 10 percent. Also, during this period, the share of area under maize, which is the main ingredient in animal feed, particularly in the poultry industry, increased by 8 percent and, because of the rapid adoption of hybrid seeds, its production increased by 130 percent (Agriculture Statistics of

[24]Pakistan Development Update: Making growth matter, World Bank, November 2016, pages 34-35.
[25] Ignoring international trade for the moment.

Pakistan, 2016-17).[26]Thus the changing pattern of demand has had a strong impact on the cropping pattern.

However, contrary to what we expected, the share of the area under wheat, the main cereal consumed in Pakistan, increased by about 5 percent during this period. The reason probably was that the Peoples Party Government (2008-2013) significantly increased the support price of wheat and since then subsidies have been provided for exporting the surpluses - wheat exports increased from 0.5 million tons per annum (1.8 percent of the output) in 2000-2004 to 1.0 million tons per annum (3.9 percent of the output) in 2010-2014[27]. The share of area under rice, the other important cereal crop, also increased during this period, but rice is a major export crop and its exports more than doubled from on average 1.6 million tons per annum (6.9 percent of the output) in 2000-2004 to 3.6 million tons per annum (12 percent of the output) in 2010-2014[28].

In brief, medium-term trends in cropping patterns in the post-2000 period were in accordance with the changing pattern of domestic (and international) demand, except in the case of wheat where the effect of government interventions dominates. This supports the results of our analysis that agricultural markets in the Punjab (and probably in Pakistan) are well integrated and price signals are transmitted efficiently between markets.

[26] In the period 2000-2004 to 2010-2014 maize yields increased by a phenomenal 120 percent, which may be compared with increases in wheat and rice yields of 17 percent and 19 percent respectively during this period.
[27] https://www.indexmundi.com/agriculture/?country=pk&commodity=wheat&graph=exports
[28] https://www.indexmundi.com/agriculture/?country=pk&commodity=milled-rice&graph=exports

Table 32: Trends in Cropping Pattern in Pakistan's Agriculture – 2000 to 2014

(Average % share of the total cropped)

Crops	2000-2004	2005-2009	2010-2014
Wheat	36.67	36.60	38.80
Cotton	13.26	13.00	12.46
Rice	10.47	11.24	11.24
Maize	4.24	4.38	4.56
Sugarcane	4.61	4.40	4.41
Pulses	6.27	6.27	5.55
Vegetables & Fruits	4.72	6.12	6.31
Oilseeds	2.64	3.17	2.81
Fodder	11.19	10.34	9.49
Other crops	5.94	4.48	4.36

Source: Author's calculations using, Agriculture Statistics of Pakistan 2017-18, 2019, Ministry of National Food Security and Research. http://www.mnfsr.gov.pk/pubDetails.aspx

6. Conclusion

For the development of a dynamic agriculture sector, efficiency of agriculture markets is critical. We posited that market efficiency is best thought of as having two elements, i.e. technical efficiency which is measured by the extent of integration of agricultural markets and economic efficiency for which marketing margins on aggregate, i.e. the percentage difference in the price paid by the consumers and that received by the farmers are the appropriate measure. We know that economic efficiency of agricultural markets in the Punjab is probably quite low because agricultural produce passes through many different hands before reaching the consumer and marketing margins at each point in the chain are high; but, due to the lack of any data on farm gate prices we are unable to test for it. Therefore, the focus of our research has been on determining the technical efficiency of the agricultural marketing system in the Punjab.

The concepts of market integration and price transmission, where market integration describes the extent to which different markets are connected to one another, have been used in many studies to measure market efficiency – which we call technical efficiency. To determine the extent of market integration we used the Agriculture Management

Information System (AMIS) dataset that has daily wholesale market prices for most crops in the Punjab for the years 2010-2017. As we had argued that non-traditional crops are more likely to be adversely affected by an outdated agricultural marketing system we selected four vegetable and fruit crops (potato, onion, mango, kinnow) and one cereal (basmati rice[29]) for analysis.

To test for strength and speed of price transmission between agricultural markets, Granger causality tests and Vector Auto Regressive (VAR) models were used. We found that potato, onion and mango markets are well integrated both horizontally and vertically, with the speed of price adjustment in most cases (mango is the exception) being very rapid. Therefore, we can say that these three markets are technically efficient. It is difficult, however, to categorically say that kinnow and basmati rice markets are technically efficient, because although both markets are vertically fairly well integrated we are unable to satisfactorily measure the extent of horizontal integration as price data were not available for a number of important producer markets. Also, as a reality check, we looked at trends in the cropping pattern over the period 2000 to 2014 and found that they are in line with the changing market demand and government price interventions.

In conclusion, we want to highlight that market integration (or what we call technical efficiency) is not sufficient for "producers and consumers [to] realize their potential gains" as has been argued by some researchers (Reddy, 2012, Varela et al., 2012) and what we call economic efficiency, is a necessary condition for these gains to be fully realized. More research is needed in the area of economic efficiency of agriculture markets, and in the case of Pakistan such research would be timely because the Punjab Agriculture Marketing Regulatory Authority (PAMRA) Act 2020 has fundamentally reformed the legal and regulatory framework for agricultural marketing in the Punjab and such a study could provide a baseline for measuring the economic impact of the legal reforms.

[29] It would have been preferable to have included wheat as the cereal crop but, because of extensive government intervention in the market, meaningful analysis of the wheat market was not possible.

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Estimation of Supply and Demand Elasticities for Major Crops Produced in Pakistan

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Abstract

This article studies the supply and demand of major Pakistani crops. We estimate supply elasticities using a Nerlovian partial adjustment process and demand elasticities using the Deaton and Muellbauer Almost Ideal Demand Systems (AIDS). We use secondary data from various Household Integrated Economic Surveys and Agricultural Statistics of Pakistan. Our estimated supply elasticities with respect to price lie between 0.1 and 0.5 for all crops. Pulses tend to have higher elasticities than traditional crops such as wheat and rice. Demand elasticities with respect to price tend to be inelastic, with the exception of poultry and fruit which appear to be luxury items. Pulses are income inelastic, implying that consumption may not rise significantly as per capita incomes and that the introduction of yield enhancing varieties will lead to lower prices.

Keywords: Supply, demand, elasticity, major crops, Pakistan.

JEL Classifications: Q11, Q19.

1. Introduction

In Pakistan wheat, sugarcane, cotton, and rice accounted for more than three-quarters of total crop output in 2015 (FAO, 2016). Wheat is the country's largest food crop in terms of production volume while cotton is both an important export commodity as well as key raw material to the local textile industry. Rice is also an important cash crop and an important export

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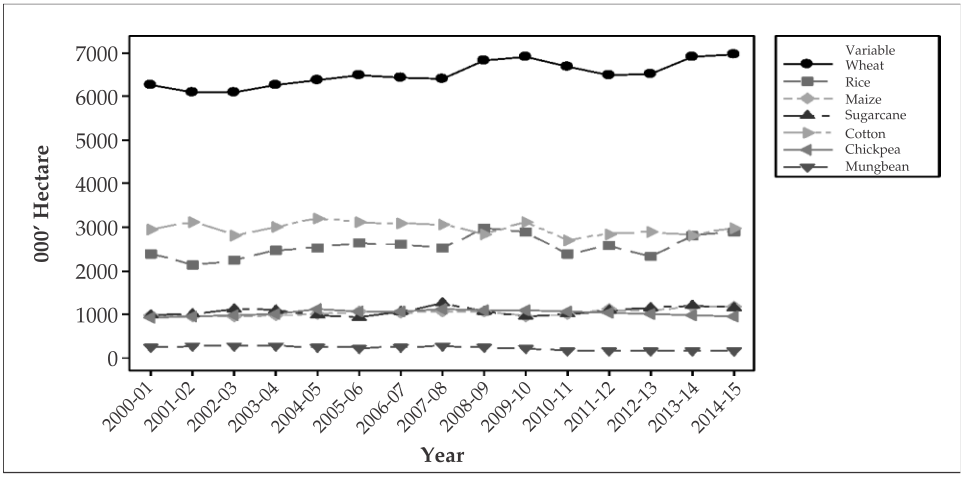
while sugarcane is used in the production of white sugar and gur (jaggery) (Ministry of Finance, 2006). The cultivated area used to grow pulses is currently around 1.15 million hectares out of which major pulses (chickpea, lentils, mung bean and mash bean) used 1.09 million hectares. Chickpea and masoor (lentils) are the major *rabi* (winter) crops while mung and mash are the important *kharif* (summer) crops.

The production of pulses is lower than that of other competing crops and has been declining due to seed quality and poor crop management so that their prices have risen steadily for over the last decade (Figure 1 and Vanzetti et al., 2018). The observed increase in prices can be attributed to falling production and growth in population and incomes (Aazim, 2013; Khan, 2015; and Junejo, 2016).

The fluctuation in the area of major crops in Pakistan is given in figure 1.

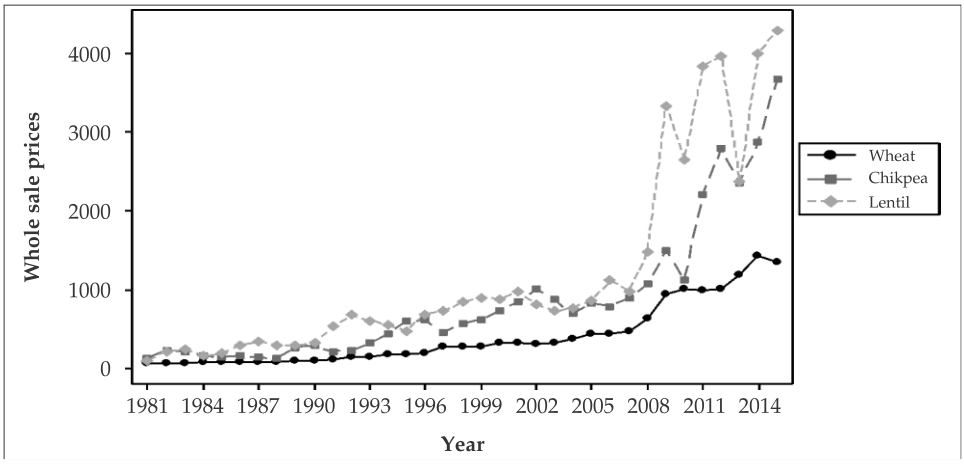
Figure 1: Area under the different crop in Pakistan in 000,Ha



Source: Agricultural Statistics of Pakistan, 2015-16

Farmers prefer to grow crops whose yields and prices are relatively predictable and in Pakistan the prices of pulses tend to be unstable, especially compared to wheat and sugar where the government operates a price stabilization mechanism. Much of this price instability is due to fluctuations in total output (Rani et al., 2012) with bumper harvests leading to lower prices.

Figure 2: Chickpea, Lentil and Wheat Prices in Pakistan



Source: Agricultural Statistics of Pakistan, Pakistan Office of Statistics

The significantly higher prices of important crops are what motivates research into understanding the consumer and producer responses to rising prices. Such an analysis is essential for policymakers attempting to design effective and pro-poor food policies. In this article, we estimate the elasticities of supply and demand for the major crops produced in Pakistan. This in turn can shed light on the potential impact of higher agricultural productivity, induced by research and development, since demand elasticities are important in determining the extent to which the benefits of a productivity enhancement will be shared between producers or consumers. If demand is inelastic, that is, not responsive to price changes, then an increase in productivity will benefit consumers. On the other hand, inelastic demand may be detrimental if the objective of policy makers is to help small producers.

2. Empirical Methodology

A. Supply Response

The production response equation of different crops is estimated at the national level data using Nerlove's partial adjustment model (Nerlove, 1958; Ali, 1998; Savadatti, 2006; and Rani, 2015; used a similar approach). The supply response function is specified as follows:

$$Y_{it} = \beta_0 + \beta_1 P_{it-1} + \beta_2 P_{jt-1} + \beta_3 Y_{it-1} + \beta_4 C_t + \beta_5 I_t + \beta_6 W_{rt} + \beta_7 W_{kt} + \beta_8 F_t + \mu_t \quad (1)$$

Y_{it}= Production of crop *i* (kilotons) in year *t*;

P_{it-1} = Lagged relative farm harvest price (FHP)/Wholesale prices of concerned crop;

P_{jt-1} = Lagged relative farm harvest price (FHP)/Wholesale prices of competing crop *j*;

Y_{it-1} = Lagged production of crop *i*;

C_t = Cropping intensity (total cropped area divided by net sown area);

I_t = Proportion of the irrigated area in the total cropped area;

W_{rt} = Weather risk during the *rabi* season measured by the standard deviation from normal rainfall during growing months of crop *i* (in mms) measured over the three preceding years;

W_{kt}= Weather risk during the *kharif* season measured by the standard deviation from normal rainfall normal during growing months of crop *i* (in mms) measured over the three preceding years;

F_t=Fertilizer prices of urea and DAP of 50 kg in Rupees

μ_t=Error term.

Supply response variables are listed in Table 1. The decision by farmers on how much of a particular crop to grow depends on the previous year prices of the crop, prices of competing crops and previous year's production. Cropping intensity measures the pressure on land and a negative coefficient for the impact of C_t indicates that an increase in the cropping intensity has a negative impact on the production of a crop. The irrigation intensity variable, I_t, measures the public and private investment in irrigation infrastructure over time. If the coefficient associated with this variable is positive, the crop has benefited from irrigation facilities.

B. Demand Response

A number of studies have used time series data to estimate demand functions (Schultz, 1938; Stone, 1953; Wold & Jureen; 1953). The estimation of demand function in this study is based on Wold's market statistics approach to derive consumption, because of the lack of direct consumption

data (which has also been used in other studies like Savadatti, 2006). We applied the Linear Approximate-Almost Ideal Demand System (LA-AIDS) methodology to estimate the demand function for all food items including pulses. This approach has also been used by other authors like Ali (1998), Ullah (2014) and Malik (2015). The model estimates both the own-price elasticity as well as cross price and income elasticities of demand. The model is specified as follows:

$$\omega_i = \alpha + +\beta_i \ln(x/p) + \mu_i \quad (2)$$

ω_i= budget share of good i

P_j= price of good j (j= 1,2,….n)

x= total expenditure on all food items

p_i= price of the ith commodity.

$\alpha, Y_{ij}\ and\ \beta_i$are the parameters in the equation. Demand response variables are listed in Table 2.

Table 1: Supply response variables:

Variable	Description
Y_{it}	Dependent variable (production of *i*th crop in kt)
$P_{G(t-1)}$	Lagged price of chickpea
$P_{M(t-1)}$	Lagged farm price of mungbean
$P_{B(t-1)}$	Lagged farm price of mashbean
$P_{L(t-1)}$	Lagged farm price of lentil
$P_{W(t-1)}$	Lagged farm price of wheat
$P_{C(t-1)}$	Lagged farm price of cotton
$P_{Z(t-1)}$	Lagged farm price of maize
$P_{S(t-1)}$	Lagged farm price of sugarcane
$P_{R(t-1)}$	Lagged farm price of rice
$Y_{i(t-1)}$	Lagged production of ith crop in kt
C_t	Cropping intensity (total cropped area divided by net sown area);
I_t	Proportion of the irrigated area in the total cropped area
F_t	Fertilizer prices of urea and DAP
W_{rt}	Weather risk during the Rabi season
W_{kt}	Weather risk during the Kharif season

Table 2: Demand response variables:

Variable	Description
W_{it}	Dependent variable (Budget share of ith food)
P_{Cp}	Price of chickpea for consumer (Rs/KG)
P_{mung}	Price of mung for consumer (Rs/KG)
P_{mash}	Price of mash for consumer (Rs/KG)
P_{lentil}	Price of lentil for consumer (Rs/KG)
P_{wheat}	Price of wheat for consumer (Rs/KG)
P_{rice}	Price of rice for consumer (Rs/KG)
P_{meat}	Price of meat(mutton, beef and fresh fish)for consumer (Rs/KG)
P_{milk}	Price of milk(fresh and pasturized, packed, dried and condensed, butter, ghee, yogurt, all converted into liquid milk equivalent)for consumer (Rs/KG)
$P_{poultry}$	Price of poultry(chicken) for consumer (Rs/KG)
P_{veg}	Price of vegetables(tomato, potato, onion, and other for consumer (Rs/KG)
P_{fruit}	Price of fruit (citrus fruits, mango, apple, melon, graphs and dry fruits) for consumer (Rs/KG)

3. Data and Results

We estimate the supply and demand elasticities using annual time series from 1981 to 2015 taken from secondary data sources. Supply side data is collected from the Agriculture Statistics of Pakistan (published initially by the Ministry of Food, Agriculture and Livestock and later by the Ministry of National Food Security and Research), the Economic Survey of Pakistan (published by the Ministry of Finance) and other statistical bulletins. To estimate demand, the use data from the nationally representative Household Income and Expenditure Survey (HIES) for the 15 years from 1984-85 to 2015-16. HIES collects detailed information on the quantity and value of consumption of various items by both rural and urban households across provinces. This information provides us with the budget share of the different food items to estimate the Linear Approximate Almost Ideal Demand System (LA-AIDS). The prices of different food items facing consumers were estimated by dividing expenditure with the respective consumption quantities. OLS was used to estimate the equation by assuming supply and demand are independent. Different variables were tested and finalized depending upon the goodness of fit and the Pearson Correlation test was used to quantify the degree and direction to which two variables are related.

Supply response parameter estimates are provided in Table 3 and are generally consistent with expectations, with the exception of maize. Own price elasticities of the various crops are between 0.1 and 0.5 and the pulses tend to have higher elasticities than the traditional crops such as wheat and rice. The estimated elasticity for maize has the opposite sign. This probably reflects the correlation in crop prices. Farmers can substitute maize with sugar and rice and if the prices of maize and these other crops move together, farmers may switch out of maize if prices of other crops rise relatively further.

The cross-price elasticities show a less consistent pattern. A negative cross-elasticity indicates a substitute in production. This is to be expected, except in circumstances where crops are typically grown together. The cross-elasticity of chickpeas with respect to the price of lentils is positive, although insignificant. For our purposes, the most important cross-elasticity is between chickpeas and wheat, because we wish to analyze the impact of removing the wheat subsidy on pulse production. The cross-elasticity is quite high, -0.52, suggesting that chickpea production is quite responsive to the price of wheat. The cross-elasticity for lentils is -0.16, less responsive but still significant. Mung is responsive to the price of maize (0.14) and mash to the price of rice (0.28). The results are similar to the study of Rani et al. (2015).

The traditional crops, wheat, sugar and maize, are not significantly affected by the prices of pulses. The exception is rice, which has a high cross-elasticity with mash (0.28). There is also substitution between rice and sugar, but rice production does not appear to be influenced by the price of maize. Wheat, which is supported by a government floor price, is not significantly affected by the prices of other crops. Lentils are found to be a substitute for mung but a complement to rice. The main conclusion to be drawn from the supply side estimates is that a fall in the price of wheat should provide a significant boost to the supply of chickpeas.

Chandrasekhara Rao (2004) examined Indian agricultural supply responses in Andhra Pradesh by using Nerlove's Partial Adjustment Model. The author found that non-price factors are more important determinants in aggregate agricultural supply than price related factors in the state of Andhra Pradesh. Mythili (2008) estimated supply responses for major crops during pre- and post-reform periods using a Nerlovian adjustment-cum-

adaptive expectation model. Their estimation is based on dynamic panel data approach with data across states in India. They found no significant difference in supply elasticities between the pre- and post-reform periods for a majority of crops. They also found that farmers tend to respond to changes by adjusting non-acreage inputs rather than shifting the acreage. This includes better technology, use of better quality inputs and altering cultivation intensity.

As far as the cropping intensity is concerned, our results find that the production of pulses is mainly concentrated in areas with low cropping intensity. This suggests that their production is normally pushed to less fertile lands, which are marginal to main cereal and cash crop production. The negative effect of cropping intensity on the supply of pulses also reflects farmers' low preference for cultivating pulses as their main crop.

Table 3: Supply responses parameters of different crops in Pakistan

	Crops								
Variable	**Chickpea**	**Lentil**	**Mung**	**Mash**	**Wheat**	**Cotton**	**Sugarcane**	**Maize**	**Rice**
$P_{G(t-1)}$	0.395***	-0.048	-	-	-0.036	-	-	-	-
$P_{L(t-1)}$	0.014	0.166**	-	-	0.030	-	-	-	-
$P_{M(t-1)}$	-	-	0.380***	-0.105	-	-0.142**	-0.060	0.026	0.228*
$P_{B(t-1)}$	-	-	-0.028	0.347****	-	0.150	0.021	-	-0.274***
$P_{W(t-1)}$	-0.582**	-0.156*	-	-	0.142*	-	-	-	-
$P_{C(t-1)}$	-	-	0.134	0.124	-	0.270	-0.145	-0.012	-0.070
$P_{S(t-1)}$	-	-	-0.015	0.285	-	-0.227	0.445*	-0.268	-0.494**
$P_{Z(t-1)}$	-	-	-0.138	-0.020	-	0.167	0.182	-0.125**	0.202
$P_{R(t-1)}$	-	-	-0.068	-0.279***	-	0.124	-0.158	0.076	0.198
$Y_{i(t-1)}$	0.605**	0.894****	0.887****	0.789****	0.209	0.260*	0.318	0.682****	0.305*
I_t	-1.104*	-0.648	0.210***	-0.453****	-0.299	-0.352	-0.053	0.831	1.167
C_t	-0.291**	-0.785	0.945**	-0.997**	0.930**	4.063***	0.058	0.847*	0.268
F_t	0.282	0.172	-0.321	-0.290	-0.012	-0.213	-0.169**	0.451****	-0.350**
W_{rt}	-0.112	-0.25**	-	-	0.002	-		-	-
W_{kt}	-	-	-0.312	-0.151***	-	0.041	0.010	-0.024**	-0.021
R-Squared	0.82	0.89	0.95	0.98	0.93	0.82	0.881	0.98	0.894
F-statistic	11.19**	28.02****	42.26****	114.08****	54.97****	8.41****	15.50****	165.71****	17.68****
DW	2.41	2.30	1.96	1.97	2.29	2.18	1.99	2.51	2.04

*****, ***, **,* imply that elasticities are significant at 1 per cent,5per cent, 10per cent and15 per cent. Estimates are based on data from 1981 to 2015.*

The own and cross prices elasticity estimates of demand for different food items in Pakistan are provided in Table 4. All the own-price elasticities have the expected signs and magnitudes. Nearly all are between 0 and -1, signifying price inelasticity and essential nature of these goods, with the exception of poultry (-1.2) and fruit (-1.1). All of the own-price elasticities are significant except for vegetables. The estimated cross-elasticities are less consistent; chickpeas are substitutes to mung and poultry but complements to wheat. Lentils are a substitute for mung and poultry but complementary to rice. Consumption of mung is affected by the price of chickpeas and poultry. Mash consumption responds to prices of chickpeas, mung and meat (beef and mutton). Wheat and rice are substitutes. Rice itself can be substituted by several foods, including wheat, chickpeas, fruit, milk and meat.

Moreover, this is confirmed by the low estimate of income elasticity, 0.20. As incomes grow, consumers prefer to switch from rice towards higher protein foods such as wheat, pulses, dairy products and meats. Pulses are somewhat substitutable with poultry, fruit and vegetables. This result is consistent with the findings of Farooq et al. (1999), Haq et al. (2011) and Malik (2015). These results may also be explained by the increased preference for dietary diversity. However, one would have expected a complementary relationship for cereal products with vegetable products in Pakistan, since cereal products are frequently consumed jointly with vegetables (especially potatoes). Our results may be driven by the impact of aggregation decisions of composite commodities.

Finally, we look at income elasticities (Table 5). As noted above, the higher protein foods are more income elastic, indicating consumers will switch into these as their incomes increase. Pulses are income inelastic, indicating that consumption may not increase significantly as per capita incomes increase. Based on income elasticities exceeding 1, meat, milk, fruit and poultry are luxury goods.

Table 4: Own and cross prices elasticities of demand of different food items in Pakistan

Prices	Food Items										
	Chickpea	Lentil	Mung	Mash	Wheat	Rice	Milk	Meat	Poultry	Fruits	Vegetable
P_{Cp}	-0.632**	0.034	0.473***	0.810****	-0.155	-0.585**	-0.008	0.301	0.782***	-0.389	-0.120
P_{lentil}	-0.737	-0.341*	-0.267	-0.490	-0.145	-0.374*	-0.359***	0.327	0.610	0.599	0.380**
P_{mung}	0.655**	0.645**	-0.859**	1.500****	0.305	0.005	0.374	-0.831	0.362	-0.169*	0.115
P_{mash}	0.135	-0.098	0.378	-0.666****	-0.063	0.131	-0.010	0.084	-0.078**	0.064	-0.123**
P_{wheat}	-0.032**	-0.270	-0.815	-0.113	-0.346***	-0.493**	-0.526	-0.329***	-0.218	-0.828	-0.132
P_{rice}	0.461	-0.316*	-0.231	-0.311***	0.128**	-0.739**	0.253	0.169	0.479	-0.174	-0.431
P_{milk}	0.040	0.377	1.164	-1.321***	-0.337	-0.714**	-0.847**	-0.142	-0.546	0.731***	-0.488**
P_{meat}	-0.929	-0.062	-0.907	0.333***	-0.675	0.220**	-0.081	-0.872***	0.957	-0. 217	0.037
$P_{Poultry}$	0.435**	0.316**	0.331***	-1.267	0.294	-0.069	-0.062	0.108*	-1.208****	-0.229	0.406
P_{fruit}	-0.057	-0.053	0.164	-0.342***	0.071	-0.124	0.015**	-0.139	-0.392	-1.091**	0.020
P_{veg}	0.567**	0.057	-0.497	0.994**	-0.208**	0.050	-0.417	0.421	0.314**	0.650****	-0.253
R-Squared	0.99	0.99	0.96	0.98	0.99	0.99	0.98	0.99	0.99	0.99	0.99
R- adjusted	0.96	0.98	0.98	0.88	0.99	0.99	0.92	0.88	0.98	0.98	0.98
F-statistic	27.91****	420.99***	1.92**	9.71****	31.41**	109.58***	68.08***	79.63***	111.54***	15.28***	108.22***
DW	2.51	2.16	2.23	2.20	2.26	2.16	2.07	2.45	2.34	2.34	2.25

*****, ***, **,* imply that elasticities are significance at 1 per cent,5per cent,10per cent and15 per cent. Estimates are based on data from 1981 to 2015.*

Table 5: Income elasticities of demand of different food items in Pakistan

Food items	Elasticity
Chickpea	0.730***
Mung	0.636**
Mash	0.098***
Lentil	0.711***
Wheat	0.446***
Rice	0.191**
Meat	1.502***
Fruits	1.646***
Vegetable	0.688****
Poultry	1.667****
Milk	1.036**

*****, ***, **,* imply that elasticities are statistically significant at 1 percent, 5 percent and 10 percent.*

4. Summary and Conclusions

There has been little attention given to food legumes by policy makers and researchers over the last few decades. Our results show that farm output prices and good weather conditions positively influence the area allocation decision made by Pakistani farmers. Farmers are price responsive and farm prices of pulses are much higher than the prices of competing crops like cereals, which should motivate pulse growers to increase the area devoted to the cultivation of pulses, though currently the production of pulses is mainly concentrated in areas of low cropping intensity. The estimated cross-elasticities of supply indicate that a reduction in the subsidized price of wheat would lead to an increase in chickpea production. An output subsidy for pulses would increase production of all pulses.

On the demand side, all the own-price elasticities greater than -1, with the exception of poultry (-1.2) and fruit (-1.1) and we find these estimated elasticities to be significant in all the cases except for vegetables. Pulses are income inelastic, indicating that consumption may not increase as incomes increase; furthermore, with inelastic demand for pulses, the introduction of yield enhancing varieties may lead to higher output and lower prices. Another interesting finding is that cereals tend to have the lowest expenditure elasticity of demand which reflect the fact that cereals are a staple of the Pakistani diet. Our findings can guide policy makers interested in projecting future food consumption and the policies required in the face of increasing incomes and a growing population.

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Foreign Aid, Political Institutions and Economic Freedom: Empirical Evidence from Selected Developing Countries

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Abstract

This article empirically examines the effects of foreign aid on economic freedom while considering the mediating role of political institutions. We contribute to the literature in two ways. First, we provide an empirical analysis of how different types of foreign aid affect the economic freedom of the receiving country. Second, we provide evidence regarding how political institutions mediate the foreign aid/economic freedom relationship. We use IV and GMM techniques to test a model using data from 40 developing countries covering the time period 1985 to 2016. Our analysis yields three main findings. First, democratic and politically stable countries enjoy more economic freedom. Second, foreign aid's net effect is to reduce economic freedom, whether we consider official development assistance (ODA) or net official assistance (NOA).Finally, economic freedom increases with both types of foreign aid if the receiving country's political institutions are more democratic and/or durable.

Keywords: Foreign aid, economic freedom, political institutions, panel data

JEL Classification: F35, P48, D02, C23

1. Introduction

The assessment of the impacts of foreign aid is well-covered in the development economics literature. Early empirical insights based on the dual gap model of Chenery and Strout (1966) focused on the aggregate macroeconomic effects of foreign aid. Further literature explored the

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impact of foreign aid on economic growth, with findings ranging from foreign aid being growth-promoting to aid having significant negative impacts. However, the effects of foreign aid are manifold in nature, covering economic, political, and social aspects that go beyond simple macroeconomics. Consequently, recent work on the effects of foreign aid look at a myriad of issues ranging from macroeconomic structure and debt management prevailing in the 1980s to major events such as natural calamities or major public health events such as the HIV/AIDS crisis in the 1990s. Since the 2000s, most foreign assistance programs are developed to address various objectives simultaneously.

Economic freedom, according to classical economic thought, stems from the existence of free markets, free trade, and protection of property rights, intended not only to enhance the growth process but to increase individual choice set.[1]Smith (1776) described a structure of natural liberty in which every individual maintains the utmost liberty that is compatible with economic freedom. The main promises of Smith's ideology were to permit laissez-faire free trade, low state spending, low taxes, and a negligibly interfering regime. Friedman (1962) defined economic freedom as "a system of free markets and private ownership that operates with limited interference from the government" and argued that economic freedom is a significant component of total freedom. Economic freedom is a precondition for political freedom, and Friedman suggests that economic organizations providing economic freedom (e.g. competitive capitalism), endorse political power by separating economic power from political power. He argued that capitalism, which is economic freedom, is a necessary condition for political freedom; however, the relationship between the two is composite and not unilateral.

Economic freedom is not only vital for the growth development, it also uplifts the social and political fabric of a country. Under economic freedom, individuals make economic decisions for themselves, motivating them to make optimal decisions, which is important for the growth and development of a country. From a social point of view, economic freedom provides personal autonomy, human dignity, and

[1] The classical liberal thought based on Smith (1776) idea "that institutions let the right of individuals to chase their own economic wellbeing will end in the prosperity of the entire humanity".

power of self-direction. And as Friedman (1962) argued, from a political point of view, economic freedom is a precondition for political freedom.

Despite a burgeoning literature, empirical proof of a positive effect of foreign aid on economic freedom has not reached a consensus. Studies on the positive impact of foreign aid on economic freedom generally highlight the expansion of public investment and tax reduction (Vasquez, 1998; Dreher & Gehring, 2012). Those studies that cast doubt on the positive impact of foreign aid on economic freedom emphasize rent-seeking in aid receiving countries (Svensson, 2000; Dreher et al., 2015; Heckleman and Knack, 2009; Powell and Rayan, 2006). Svensson (2000), for example, suggested that receiving aid can destroy the quality of safety regulations by encouraging rent-seeking and corruption that in turn slow down the process of economic freedom in the receiving country.

The inconclusiveness in the literature on the subject is the first motive to take on this study. The second motive is to capture the impact of governance-related conditions that both the donor organizations (UN, IMF, World Bank) and donating nations started requiring in early the 1990s in order to make ensure the best utilization of foreign aid. Hence, the extent to which a country can benefit from foreign aid in the form of economic freedom is believed to be sensitive to the structure of political institutions in a particular country.

Keeping in view the mediating role of institutions in the foreign aid - economic freedom nexus, we hypothesize that the development of political institutions, a democratic regime, and continuity in political processes (durability) should mitigate the negative impact of foreign aid on the economic freedom of the receiving countries. Thus, we attempt to assess the impact of foreign aid on a receiving country's economic freedom conditional on the structure of its political institutions. Unlike existing explorations on the subject, our contribution is that we take into account *separately* the two different types of foreign aid, that are official development assistance (ODA) and net official assistance (NOA). Moreover, we provide evidence on the role a country's political institutions play in the foreign aid -economic freedom relationship.

We study 40 developing countries for the time period of 1985 to 2016. Three motives limit our analysis to a sample of 40 countries only.

First, we focus on countries whose economies heavily depend on external sources including foreign aid. Second, the sample countries share some common characteristics: large governments, highly regulated monetary and exchange rate policies, and lack of legal structures and security of private property. Finally, most of the sample countries are passing through a transitional period of their political systems.

The rest of the study is organized as follows. Sections 2 presents a review of the related studies on the subject. Section 3 discusses our methodology which includes a discussion of the empirical model, definition and construction of variables, sample and sample selection criteria, and estimation methodology. Section 4 discusses our results. Finally, section 5 offers some conclusions.

2. Insights from the Literature

Since the late 1940s with the advent of the Marshall Plan, international economic collaboration has attempted to enhance the growth and development process. Mainly, three dimensions have been covered in related literature on foreign aid; that is, its effects, distribution, and driving factors. As far as the effects of foreign aid are concerned, the empirical insights mostly based on the dual gap model of Chenery and Strout (1966), which underlines the aggregate macroeconomic effects of foreign aid.

Studies promoting the positive impact of foreign aid on macroeconomic aggregates generally explain aid's impact as filling the dual gaps facing the recipient countries (Papanek, 1973; Bacha, 1990; Taylor, 1994; Islam, 1992; Thirlwall, 1999). These studies also point out that, without foreign aid, the fiscal gap limits the capacity of the public sector to invest in the infrastructure required for long-run growth and development. Moreover, foreign aid improves the growth capacity of receiving countries by filling of savings-investment gap.

Others argue that the positive effects of aid on economic growth are conditional on the receiving country's economic policies. Burnside and Dollar (2000) analyze the relationship between aid, policy, and economic growth using a data set of 56 developing countries and find that aid proves

beneficial for economic growth in those countries maintaining good fiscal, monetary, and trade policies.

On the other hand, a number of studies cast doubt on the macroeconomic benefits of foreign aid (Weisskoff, 1972; Mosely, 1986; Mosely and Hudson, 1995; Boone, 1996; Easterly, 2001). Their arguments stem from Olsen's (1965) ideas on free-rider problems and coordination failures. Foreign aid, according to these studies, creates free rider problems and a rent-seeking environment to the detriment of indigenous resource mobilization.

Considering the diversity of impacts of foreign aid, gradually empirical exploration extended beyond the domain of macroeconomic effectiveness, with economic freedom becoming one of the topics covered in the evolving foreign aid literature. We consider the streams of literature deliberating both direct and indirect effects of foreign aid on the economic freedom of recipient countries.

The indirect impacts of foreign aid on economic freedom take effect through a number of different transmission channels. For instance, some studies argued that the effect of foreign aid on economic freedom takes place through conditionality, since donor countries often directly tie the transfer of money to certain aims and conditions. Hence, the impact of foreign aid on economic freedom of the receiving country is conditional on both the nature of conditions imposed and donor country implementation capacity. Conditional aid does not always enhance economic freedom, however. For instance, Alesina and Dollar (2000), Meernik, et al. (1998), and Schraeder, et al. (1998) argue that during the Cold War era[2] the provision of aid by the western nations to less-developed nations were mainly tied to the attainment and safeguard of armed, tactical and political aims; hence, during this period, given the non-progressive nature of aid, economic freedom of the receiving countries could not improve.

Other researchers examined the role of the recipient country's own characteristics in the foreign aid -economic freedom relationship. This literature explored the mediating role of the institutional, governance,

[2]The state of political tension from1947–1991 after World War II.

and political regimes. Aid can either strengthen or weaken economic institutions. The latter can occur when the substitutability of foreign aid for domestic revenue creates a rent-seeking environment. For instance, Devarajan et al. (2001) argue that aid receiving administrators take aid as an alternative source of revenue collection, whereas political leaders pursuing their own interests use aid in unproductive ways. Similarly, Heckelman and Knack (2009) found that aid had no impact on economic freedom in the receiving countries. Some others examine the role of the nature of the ruling party in the foreign aid and economic freedom relationship. Tawaiah, and Zakari (2019), for example, document that right-leaning, capitalist parties allocate more resources to create the enabling environment for the private sector while leftist parties allocate more aid inflows for the pro-poor projects such as short-term poverty reduction. For instance, Dutta and Williamson (2016a) carried out a comprehensive study and examined the impact of foreign aid on economic freedom conditional on the quality of political institutions using a data set of 108 countries from 1971 to 2010. They find that economic freedom improves with aid in countries that are democratic, but it has a negative impact in the case of autocracies.

3. Methodology

The methodology section includes four subsections; the first section (3.1) presents the specification of the empirical model. Section 3.2 describes the definition and construction of variables under consideration. Section 3.3 describes the sample and sample selection criteria, and section 3.4 presents the estimation techniques.

3.1 Empirical Model

Our empirical model is based largely on Dutta and Williamson's (2016a) empirical model which analyzes the impact of foreign aid on economic freedom conditional on political institutions. Hence, in order to examine the impact of different types of foreign aid on economic freedom and to explore the role of political institutions we closed follow Dutta and Williamson (2016a) and estimated the empirical model in Equation 1.We diverge from Dutta and Williamson (2016a) in two ways. First, since the presence of unobserved heterogeneity implies that estimates of common parameters are subject to an incidental parameter bias that may be

substantial in large samples (Hahn and Newey, 2004), we reduce the sample to 40 countries. Further, these 40 countries are selected to be similar (having experienced both aid dependency and a transition in political regime), as Bonhomme and Manresa (2015) argue that grouped patterns of unobserved heterogeneity in cross country analyses reduce the incidental parameter bias. Secondly, unlike Dutta and Williamson (2016a) that used the overall foreign aid, we analyze the impact of different types of foreign aid on economic freedom.[3]

$$\mathrm{EF_{it}} = \alpha_0 + \alpha_1 \mathrm{EF_{it-1}} + \beta \mathrm{AID_{it-1}} + \gamma \mathrm{POLINST_{it-1}} + \alpha_3 (\mathrm{AID_{it-1}} * \mathrm{POLINST_{it-1}}) + \theta \mathrm{X_{it-1}} + \eta_i + \eta_t + \varepsilon_{it} \quad (1)$$

Where economic freedom ($\mathrm{EF_{it}}$) is our dependent variable in country i and period t. $\mathrm{EF_{it-1}}$is the lagged dependent variable,$\mathrm{AID_{it-1}}$represents foreign aid which is our variable of interest and covers two types of foreign assistance, that are Official Development Assistance (ODA) and Net Official Assistance (NOA). $\mathrm{POLINST_{it-1}}$represents lagged measures political institutions that comprise democracy and durability. $X_{it-1}$is the vector of control variables. η_i is a country fixed effect, η_t is a period fixed effects and ε_{it} is error term which is normally distributed.($AID_{it-1} * \mathrm{POLINST}_{it-1}$) is the interaction term, which shows the impact of foreign aid on economic freedom conditional on the political institutional structure of country i.

3.2 Definition and Construction of Variables

The dependent variable is Economic Freedom($\mathrm{EF_{it}}$) is and index composed of five components: i) Size of Government ii) Monetary Policy and Price Stability iii) Legal Structure and Security of Private Property iv) Freedom to Trade without Regulations v) Regulation of Credit, Labor and Business. The index value ranges from 0-10 with a higher score showing greater economic freedom[4].

Among explanatory variables, foreign aid (AID_{it-1}) is our main variable of interest. We have used two different measures of aid in our analysis, namely Official Development Assistance($\mathrm{ODA_{it-1}}$)and Net

[3]Section 2.3 presents a detailed discussion on the selection criteria of Country's sample and time period.
[4] Data is available at www.Fraserinstitute.org.

Official Assistance($\mathrm{NOA}_{\mathrm{it}-1}$). ODA, which is an extensive measure of assistance, is taken as a percentage of GNI. It contains concessional loans and grants and also bilateral and multilateral aid. Net Official Assistance is a flow from official donors to those in part II of the Development Assistance Committee (DAC) list of receivers, which is in current U.S. dollars.[5]Moreover, because of potential endogeneity and reverse causation, foreign assistance is lagged and successively instrumented. The data on economic freedom and foreign assistance are taken from the Fraser Institute (2016) and the World Bank's World Development Indicators (WDI) 2016, respectively.

In order to capture the role of political institutions, we measure their quality (democracy) and stability (durability). The first component (democracy) ranges from +10 to – 10, where +10 represents strong democracy and -10 represents strong autocracy with a mean of 2.5 and a standard deviation of 6.0. The second component (durability) shows the number of years a political regime changes and ranges from 0 to 194 having a mean of 16.6 and a standard deviation of 21.7. The data on both are collected from the Polity IV database[6].In order to capture the role of political institutions in the foreign aid -economic freedom nexus, we used a number of interaction terms in our empirical analysis. As two components of political institutions and two proxies of foreign aid are used, we obtain four different interaction terms, namely ODA with democracy ($ODA_{it-1} * DEM_{it-1}$), and ODA with durability($ODA_{it-1} * DUR_{it-1}$). In the same way, ($NOA_{it-1} * DEM_{it-1}$) and ($NOA_{it-1} * DUR_{it-1}$) are the interaction terms for net official assistance with democracy and net official assistance with durability respectively.

We used a set of control variables considering their relevance as a determinant of economic freedom and their potential for affecting the response of economic freedom to foreign aid. For instance, as suggested by Boockmann and Dreher (2003), economic freedom increases with economic

[5]In 1993 - with new aid requirements in the transition economies of Eastern Europe and reduced aid needs in East Asia due to rapid progress - a new list was devised. It was divided into two parts. Part I: Only aid to "traditional" developing countries counted as Official Development Assistance (ODA), for which there is a long-standing United Nations target of 0.7% of donors' national income. Part II: Aid to "more advanced" developing and eastern European countries were recorded separately as "official aid". Net Official Assistance (NOA) is provided to emerging nations on the same terms and conditions as in the case of ODA.

[6]Available at www.systemicpeace.org/inscrdata.html.

prosperity. Similarly, Knedlik and Kronthaler (2007), Heckelman and Knack (2005), and Dreher and Gehring (2012) argued that as a country becomes richer, its citizens may demand more economic freedom. Hence, in order to capture the growth effect on economic freedom, we used lagged GDP growth ($GDPG_{it-1}$) and lagged GDP per capita ($GDPPC_{it-1}$)as control variables.

We control for population growth ($POPG_{it-1}$)in our empirical model for the following reasons. First, population growth provides an opportunity for the accumulation of human capital, which is essential to economic freedom. Second, economic activity increases with an increase in population, and with it the opportunities to pursue economic freedom. Third, population growth yields positive dividends for the younger population who will want to claim more economic freedom as indicated by Young and Sheehan (2014). In addition, it is generally proposed that when a greater share of the working-age population are engaged in production, then they desire more economic freedoms. In this context, labor force participation ($LFPR_{it-1}$) is also controlled for in our empirical model. Finally, we include trade openness ($TOPEN_{it-1}$)to control for exposure to the rest of the world. Data on these variables are collected from WDI data set of the World Bank[7].

3.3 Country's Sample and Time Period Selection Criteria

We carry out the analysis on a cross-country panel of 40 developing countries selected from four different aid-receiving regions.[8] Within these regions, three motives limit our analysis to a sample of 40 countries only. First, few of the sample countries have sufficiently mobilized their own indigenous resources, so that their development is firmly contingent on external sources. Second, the sample countries share some common characteristics; for instance, most of the countries have large governments, highly regulated monetary and exchange rate regimes, a lack of legal structure and security of private property, which limits their economic freedom. Finally, most of the sample countries have passed through a transitional period of their political system, so that they have experienced both democracy and autocracy. Owing to these

[7] See appendix A for definition and construction of variables under consideration.
[8]These four regions are South Asia, East Asia, Latin America, and Sub-Saharan Africa. See appendix B for the list of countries under consideration.

characteristics, the economic freedom of these countries should be affected by foreign aid and political institutions.

The time period from 1985-2016 reflects data availability and the history of donor conditionalities. First, a long time series for those critical variables including economic freedom and political institutions is not available. Second, most of the conditionalities have only been enforced since the early 1990s.

Empirical Methodology

In estimating (1),we have to consider the issues of heterogeneity across cross-sections and endogeneity with respect to foreign aid (Fuchs et al., 2014; Dutta and Williamson, 2016a). With regards to the importance cross-sectional heterogeneity, the Breusch-Pagan heterogeneity test shows that in all specifications the null hypothesis ($\hat{\sigma}^2 = 0$ constant variance) is rejected,indicating that cross-country specific fixed effects matter.[9]

Second, to handle the endogeneity problem, we estimated equation (1) with two different estimation techniques: Instrumental Variables (IV) and System GMM techniques. As foreign aid and its interaction terms subject to reverse causality, they are treated as endogenous variables and are instrumented for. The generated instruments (GMM) come from moment conditions for the dynamic panel estimators, whereas the external instruments (IV) have come from the received literature (Fuchs et al. 2014; Dutta and Williamson, 2016a). These studies have focused on voting alignment with major supporters in the United Nations General Assembly (UNGA) and impermanent affiliation in United Nations Security Council (UNSC). Following these authors, we use the same variables as external instruments. The first instrument is polling coincidence with chief aid givers in the UNGA. Barro and Lee (2015) argue that the developing countries that have a closer tie with the US can indeed get more aid inflows as compared to other developing countries. Second, an instrument that has been used is the main polls in the UNGA, which are in line with the elective configuration of major aid donor countries like Great Britain, United States, Italy, Japan, and France. These two variables are lagged one period. The third instrument is the temporary membership in the United

[9] See appendix C for the Breusch-Pagan heterogeneity test.

Nation Security Council (UNSC), since empirical studies show that countries that have temporary membership in the council may receive relatively more aid than non-members counterparts.

Next, we move towards GMM estimation that generates instruments through moment conditions for the variable of interest (foreign aid) and its interaction terms. Taking aid and its interaction terms endogenous, system GMM gives two sets of equations that are in level and difference forms (Fuchs et al. 2014).

The GMM estimators utilize internal instruments using a lag of the dependent and previous observations of explanatory variables, which addresses endogeneity problems. However, the difference GMM estimator has some noteworthy shortcomings as specified by Alonso-Borrego and Arellano (1999), and Bond et.al (2001) that, in the case of difference regression, equation lagged levels of variables are weak instruments that in turn cause bias and inefficiency in the estimated regressions. Hence, to reduce these potential pitfalls in our estimator, we use the system GMM estimator developed by Arellano and Bover (1995) that use both differences and levels regression equations and combine them into one system. The consistency of the GMM estimator depends on the validity of the instruments used. For addressing this problem, we used two specification tests suggested by Arellano and Bover (1995). The first is the Sargan test to test the validity of all instruments used. The Sargan test tests the null hypothesis of the validity of over-identifying instruments. The second test is that of serial correlation to test whether error terms are second-order serial correlated.

We have carried our estimations with eight different specifications. First, we have examined directly the impact of aid on economic freedom using two different types of foreign aid namely ODA, and NOA. Second, we examined the impact of foreign aid on economic freedom conditional on political institutions (democracy, durability). Finally, the robustness of estimated results has been checked in the last two specifications.

4. Empirical Findings

The following subsections 4.1 and 4.2 present the estimated results of IV and GMM estimation techniques respectively.

4.1 IV Estimation

Table 1 presents the estimated results of our IV empirical model where we regressed economic freedom (EF_{it})on two different proxies of foreign aid along with conditional terms and a set of control of variables. In order to address the endogeneity of foreign, we used six external instrumental variables.

Table 1. IV Estimated Results (Dependent Variable is Economic Freedom)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Const.	4.862*	4.034*	3.954*	4.314*	3.933*	4.191*	3.945*	3.961*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EF_{it-1}	0.803*	0.811*	0.833*	0.890 *	0.835*	0.811*	0.851*	0.854*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$GDPG_{it-1}$	0.511**	0.024**	0.026**	0.020**	0.038*	0.016***	0.250***	0.252**
	(0.034)	(0.036)	(0.033)	(0.05)	(0.003)	(0.076)	(0.061)	(0.053)
$POPG_{it-1}$	-0.113	-0.009	-0.016	-0.030	-0.008	-0.024	-0.33	-0.354
	(0.233)	(0.697)	(0.583)	(0.293)	(0.803)	(0.182)	(0.266)	(0.234)
$LFPR_{it-1}$	0.017*	0.023*	0.022*	0.015*	0.133*	0.015**	0.031*	0.028*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.029)	(0.000)	(0.000)
ODA_{it-1}	-0.105**	-	-0.072*	-	-0.046*	-	-0.07*	-0.066*
	(0.000)		(0.008)		(0.001)		(0.002)	(0.003)
NOA_{it-1}	-	-0.104**	-	-0.434*	-	-0.222**	-	-
		(0.042)		(0.000)		(0.028)		
DEM_{it-1}	0.038*	0.009*	0.018*	0.024*	0.022**	0.017*	0.021*	0.020*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.054)	(0.000)	(0.001)	(0.000)
DUR_{it-1}	0.003**	0.004*	-	-	0.007*	0.043*	-	-
	(0.033)	(0.001)			(0.001)	(0.000)		
$(ODA_{it-1} * DEM_{it-1})$	-	-	0.009*	-	-	-	0.0015**	0.003**
			(0.000)				(0.074)	(0.028)
$(NOA_{it-1} * DEM_{it-1})$	-	-	-	0.076*	-	-	-	-
				(0.000)				
$(ODA_{it-1} * DUR_{it-1})$	-	-	-	-	0.001**	-	-	-
					(0.041)			
$(NOA_{it-1} * DUR_{it-1})$	-	-	-	-	-	0.008*	-	-
						(0.003)		
$TOPEN_{it-1}$	-	-	-	-	-	-	0.010*	0.010*
							(0.000)	(0.01)
$GDPPC_{it-1}$	-	-	-	-	-	-	-	0.023*
								(0.003)
R^2	0.77	0.78	0.77	0.71	0.76	0.78	0.76	76
Obs.	1279	1273	1279	1273	1279	1274	1279	1279
No. of Ins.	12	12	12	12	12	12	12	12
Sargan P.	0.67	0.45	0.75	0.31	0.01	0.70	0.75	0.45

Note: P-value is in parenthesis, *, **, *** shows level of significance at 1%, 5%, and 10% respectively.

In table 1, model 1 illustrates the direct effect of foreign aid on economic freedom of the aid receiving country. The result shows that foreign aid captured by official development assistance(ODA_{it-1})enters the model with a negative sign, which is statistically significant. The result indicates that official development assistance has a negative effect on the economic freedom of the receiving countries. The following reasons may explain why foreign aid may pose a negative impact on economic freedom. For instance, Heckelman and Knack (2008) stated that foreign aid can prove ruinous for economic freedom in those countries that are continuously receiving foreign aid but never taking up growth-related reforms. Powell and Rayan (2006), Dutta and Williamson (2016a) stated that foreign aid has a negative effect on economic freedom in aid receiving countries where strict rules have little regard to the wishes and welfare of their people.

In model 2, official development assistance is replaced with the net official assistance(NOA_{it-1}). Like ODA, the coefficient on net official assistance maintains a negative sign, which is also statistically significant. This points toward the statement that economic freedom shrinks with foreign aid of any kind. The results are in line with the findings of Powell and Ryan (2006); Heckelman and Knack (2008); Dreher et al. (2015), and Dutta and Williamson (2016a). In both models (1, 2) political institutions, measure as democracy (DEM_{it-1}) and durability (DUR_{it-1}) enter the model positively and statistically significant. The result indicates that countries enjoy more economic freedom when their political institutions are either more democratic or more durable (or both).

As the study is devoted to exploring the joint role of political institutions and foreign aid on economic freedom, different interaction terms of foreign aid and political institutions have been included as explanatory variables. In models 3and 4 we considered the interaction terms of ODA and democracy ($ODA_{it-1} * DEM_{it-1}$)and net official aid and democracy ($NOA_{it-1} * DEM_{it-1}$), and they are each statistically significant; this signifies the important role of democratic institutions for the effectiveness of both types of aid in increasing economic freedom. In democratic regimes, the representative body generally uses foreign aid for the interests of the public rather than for their own benefits as in the case of autocratic regimes. Dutta and Williamson (2016a), Dutta et al.

(2013), Bearce and Tirone (2010) and Dunning (2004) found similar results.

In models 5 and 6, the role of political stability is investigated. In this context, the interaction terms of official development assistance and durability ($\mathrm{ODA}_{\mathrm{it}-1} * \mathrm{DUR}_{\mathrm{it}-1}$)and net official assistance and durability ($\mathrm{NOA}_{\mathrm{it}-1} * \mathrm{DUR}_{\mathrm{it}-1}$) are used in order to analyze the role of durable political rules in foreign aid's efficacy in enhancing economic freedom. The interaction terms each enter the model positively and significantly, indicating that countries which hold durable political rules gain greater benefits from ODA and NOA through greater economic freedom. Johnson and Subramanian (2005) argued that foreign aid had no ability to improve institutions by itself, but already improved ones could use foreign aid for progressive purposes that in turn increased demand for economic freedom.

In models 7 and 8, the role of the political regime (democracy) is again investigated in foreign aid and economic freedom nexus by adding more control variables in the model. The estimated values of interaction terms show that, with the inclusion of control variables trade openness ($\mathrm{TOPEN}_{\mathrm{it}-1}$), and GDP per capita ($\mathrm{GDPC}_{\mathrm{it}-1}$), the estimated coefficients of the variables of interest and interaction terms remain unchanged.

The control variables GDPgrowth ($\mathrm{GDPG}_{\mathrm{it}-1}$), population growth ($\mathrm{POPG}_{\mathrm{it}-1}$), labor force participation ($\mathrm{LFPR}_{\mathrm{it}-1}$) are common to all specifications. Results presented in Table 1 shows that, except for population growth, these variables are important in the determination of economic freedom. GDP growth positively contributes to economic freedom in line with the literature; for example, Boockmann and Dreher (2003) argue that as a country becomes richer its citizens may demand more economic freedom. The coefficient on population growth($\mathrm{POPG}_{\mathrm{it}-1}$)maintainsis negative but it is statistically insignificant in all specifications. The result does not support the Young and Sheehan (2014) hypothesis that a larger population lays claim to more economic freedom. Labor force participation($\mathrm{LFPR}_{\mathrm{it}-1}$) is significant and positively related to economic freedom. This may be due to the reason that when more people are employed then they may be empowered to demand greater economic freedoms. Trade openness ($TOPEN_{it-1}$) has a positive

effect on economic freedom. Coviello and Islam (2006) and Knedlik and Kronthaler (2007) obtained similar findings for the relationship between economic freedom and trade openness. The model is dynamic as the lagged dependent variable (EF_{it-1})has been introduced as an explanatory variable. The coefficient of EF_{it-1} is positive and highly significant across all of the specifications. This indicates that existing economic freedom is strongly influenced by its past level.

4.2 GMM Estimation

An alternate method to address the problem of endogeneity is the GMM estimation technique, using its own generated instrumental variables. Table 2 presents the GMM estimated results of our eight different specifications.

Table 2: GMM Estimated Results (Dependent Variable is Economic Freedom)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EF_{it-1}	0.762*	0.754*	0.791*	0.762*	0.774*	0.760*	0.752*	0.755*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.00)	(0.000)	(0.000)
$GDPG_{it-1}$	0.030**	0.033*	-0.004	0.0345*	0.026**	0.037*	0.02***	0.02***
	(0.048)	(0.007)	(0.273)	(0.004)	(0.028)	(0.002)	(0.094)	(0.08)
$POPG_{it-1}$	-0.05	-0.090	-0.91	-0.75	-0.093	-0.074	-0.068	-0.014
	(0.104)	(0.211)	(0.201)	(0.110)	(0.141)	(0.202)	(0.113)	(0.212)
$LFPR_{it-1}$	0.015*	0.013*	0.025*	0.018*	0.046*	0.030**	0.035*	0.022*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.029)	(0.000)	(0.000)
ODA_{it-1}	-0.011**	-	-0.011	-	-0.010**	-	-0.011**	-0.011**
	(0.024)		(0.164)		(0.020)		(0.043)	(0.041)
NOA_{it-1}	-	0.036**	-	0.039**	-	0.013***	-	-
		(0.031)		(0.022)		(0.07)		
DEM_{it-1}	0.027*	0.021*	0.033*	0.578	-	-	0.027*	0.026*
	(0.002)	(0.000)	(0.002)	(0.109)			(0.004)	(0.005)
DUR_{it-1}	0.003**	0.004**	-	-	0.005***	0.014***	-	-
	(0.012)	(0.044)			(0.063)	(0.082)		
$ODA_{it-1} * DEM_{it-1}$	-	-	0.001***	-	-	-	0.006**	0.006**
			(0.073)				(0.036)	(0.039)
$NOA_{it-1} * DEM_{it-1}$	-	-	-	0.001**	-	-	-	-
				(0.041)				
$ODA_{it-1} * DUR_{it-1}$	-	-	-	-	0.003**	-	-	-
					(0.047)			
$NOA_{it-1} * DUR_{it-1}$	-	-	-	-	-	0.007**	-	-
						(0.030)		
$TOPEN_{it-1}$	-	-	-	-	-	-	0.001**	0.001**
							(0.049)	(0.041)
$GDPPC_{it-1}$	-	-	-	-	-	-	-	0.006***
								(0.078)
R^2	0.58	0.60	0.62	0.57	0.63	0.60	0.61	0.62
Obs.	1199	1193	1199	1193	1199	1193	1199	1199
No. of Ins.	482	482	483	483	483	484	485	486
Sargan P. Value	0.34	0.37	0.54	0.31	0.40	0.37	0.45	0.35
P Value of Auto-Corr.	0.35	0.50	0.33	0.45	0.41	0.33	0.36	0.41

Note: P-value is in parenthesis, *, **, *** shows level of significance at 1%, 5%, and 10% respectively.

Model 1 shows that like the IV results, official development assistance ($0DA_{it-1}$)enters the model negatively.In model 2, ODA is replaced with net official assistance ($N0A_{it-1}$). As opposed to the IV estimation, in GMM estimation net official assistance has a positive and significant impact.

To explore the role of political institutions in foreign aid, economic growth relationship, in model 3 and 4 we included the interaction terms of ODA and democracy ($\mathrm{ODA}_{\mathrm{it}-1} * \mathrm{DEM}_{\mathrm{it}-1}$)and net official assistance and democracy ($\mathrm{NOA}_{\mathrm{it}-1} * \mathrm{DEM}_{\mathrm{it}-1}$). Like the IV results, the interaction terms are positive and statistically significant.

In model5 and6, we investigated the role of political stability (durability) $\mathrm{DUR}_{\mathrm{it}}$ on the foreign aid -economic freedom relationship. Durability has a positive and statistically significant impact indicating that countries enjoy more economic freedom when they have a relatively stable political system. At the same time, like the IV estimates, the interaction terms of ODA and durability ($\mathrm{ODA}_{\mathrm{it}-1} * \mathrm{DUR}_{\mathrm{it}-1}$)and of net official assistance and durability ($\mathrm{NOA}_{\mathrm{it}-1} * \mathrm{DUR}_{\mathrm{it}-1}$) enter the model positively and significantlyhave significantly positive impacts, indicating that foreign aid does best in raising economic freedom when the country's political rules are more durable.

In models7 and 8, the role of democracy is re-examined after we add more control variables into the model. The estimated coefficients of democracy and its interactions with the different measures of aid are unchanged with the inclusion of the additional control variables.

4.3 Robustness Checks

The empirical analysis carried out with both IV and GMM estimation techniques. However, the consistency of IV and GMM estimator depends on the validity of instruments used in the regression. Since the null hypothesis of Sargan test is that *over-identifying restrictions are valid*, acceptance of the null hypothesis gives support to the model. For both the IV and GMM estimates in Tables1 and 2, the p-values of the Sargan test shows that the null hypothesis is not rejected in all eight specifications, which indicates that the instruments are correctly specified. Next, in the case of the GMM estimation, the serial correlation property of the original error term is tested as suggested by Arellano and Bond (1991). The p-value of second-order serial correlation presented in Table 2 indicates that the null hypothesis *no serial correlation* is not rejected. This indicates that the original error term is not serial correlated. Hence, we cannot reject the validity of the proposed instrument (one lag of dependent variable is a valid instrument) and do not require higher-order lags of the dependent variable.

5. Conclusion

Foreign aid is one of the important external sources for financing growth and development in many countries. However, very often, donors put conditions that can shape the economic freedoms of the recipient country. Hence, is important to investigate the effect of foreign aid on the economic freedom of the recipient countries. Moreover, many of the conditions attached to foreign aid are governance-related, which suggests that it important to investigate the role of political institutions as mediators. This study thus attempted to analyze the effect of foreign aid on economic freedom and explore the role of political institutions as mediators. The findings of the study reveal that, by themselves, both types of foreign aid (ODA, NOA) have a negative effect on economic freedom in most specifications. Besides, the empirical evidence shows that political institutions (democracy and durability) influence the impact of foreign aid has on economic freedom. This is shown by the fact that in all of our estimated specifications, the interaction terms have a positive coefficient. The positive effect of foreign aid on economic freedom of the receiving countries is specific to more democratic regimes. Similarly, the evidence indicates that foreign aid proves more helpful in countries that have more durable political rules.

Despite certain limitations of the study, including limited sample size, we believe our findings contribute to the literature on the effects of foreign aid on economic freedom. Our findings reveal a positive impact of foreign aid on economic freedom are more likely in the presence of democracy and durability in the political rules. These results suggest the role of state policies aimed at strengthening political institutions in order to obtain the maximum benefits of foreign aid in terms of growth and development.

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Appendix

Appendix A: Definition, Construction of Variables under Consideration

Variables	Description	Definition	Sources of Variable	Sources of Data
Dependent Variable	Economic Freedom(EF_{it})	Index of economic freedom is; size of government, monetary policy and price stability, legal structure and security of private property, freedom to trade without regulations, and regulation of credit, labor and business. It ranges from 0-10.	Gwartney et al. (2015	Fraser Institute
Independent Variable	Official Development Assistance(AID_{it})	It is net disbursement of ODA received by a country as a fraction of gross domestic national income with t-1 representing lagged one period.	WDI	WDI
Independent Variable	Net Official Aid($AIDN_{it}$)	Aid flows (net of repayments) from official donors to countries and territories in part II of the DAC list of recipients. Data are in current U.S. dollars.	WDI	WDI

Variables	Description	Definition	Sources of Variable	Sources of Data
Independent Variable	Democracy (DEM_{it})	It is polity2 and the variable ranges from -10 to 10 with 10 representing a strong democracy.	Polity IV database	Polity IV database
Independent variable	Durability (DUR_{it})	It is the number of years since the most recent regime change.	Polity IV database	Polity IV database
Control Variable	GDP Per Capita($GDPC_{it}$)	It is the log gross domestic product per capita, 2005 constant U.S. dollars.	WDI	WDI
Control Variable	Population Growth($POPG_{it}$)	It is the annual population growth rate (%).	WDI	WDI
Control Variable	GDP Growth ($GDPG_{it}$)	It is the annual growth rate (%).	WDI	WDI
Control Variable	Labor Force Participation Rate($LFPR_{it}$)	It is the percentage of male labor force participation.	WDI	WDI
Control Variable	Trade Openness ($TOPEN_{it}$)	It is the sum of imports plus exports of goods and services as a share of gross domestic product.	WDI	WDI
Instrumental Variable	UN Votes with US	It is the United Nation voting line with United states.	Dreher et al.,2011	
Instrumental Variable	UN votes with Fra	It is the United Nation voting line with France.	Dreher et al.,2011	
Instrumental Variable	UN votes with GB	It is the United Nation voting line with Great Britain.	Dreher et al.,2011	

Variables	Description	Definition	Sources of Variable	Sources of Data
UN votes with Ita Instrumental Variable		It is the United Nation voting line with Italy.	Dreher et al.,2011	
UN votes with Jap Instrumental Variable		It is the United Nation voting line with Japan.	Dreher et al.,2011	
$UNSC_{t-2}$ Instrumental Variable		It is a dummy variable representing temporary membership on the United Nations Security Council, lagged two periods.	Dreher et al.,2011	

Appendix B: List of Countries under Consideration

South Asia	East Asia	Latin America		Sub-Sahara Africa	
Bangladesh	Indonesia	Argentina	Guatemala	Chad	Nigeria
India	Malaysia	Brazil	Haiti	Ethiopia	Sierra Leo
Pakistan	Mongolia	Bolivia	Honduras	Ghana	Tanzania
Sri-Lanka	Philippine	Chile	Mauritania	Madagascar	Togo
	Thailand	Colombia	Panama	Malawi	Uganda
	Vietnam	Cost Rica	Peru	Mali	Zambia
		Ecuador	Paraguay	Namibia	Zimbabwe
		El Salvador		Niger	

Appendix C: Bruesh and Pagan Test Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Chi^2	186.82	156.3	188.57	155.70	185.00	155.12	189.6	190.0
P-Value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

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