International trade, foreign direct investment and the phenomenon of child labor

The case of Pakistan

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Abstract

Purpose – The purpose of this paper is to investigate the causal links between, foreign direct investment (FDI), openness through trade, poverty, value added of agriculture sector as share of GDP, urban population and child labor by using annual data for Pakistan over the period 1970-2003.

Design/methodology/approach – The methodological framework for causality testing is a multivariate vector autoregression (VAR) model. This permits investigation of the importance of factors on the incidence of child labor in Pakistan. More generally, this study seek to establish the causal link between these factors and child labor, which might suggest important implications for eradicating child labor's strategies for Pakistan.

Findings – This study presents strong and robust evidence that in the long-run trade openness raises the output of the exportable sector and increases the demand for child labor as well as the child-wage. However, FDI is found to lower the incidence of child labor, indicating that because of low labor standards and a high incidence of child labor, Pakistan is not attracting a greater inflow of FDI.

Practical implications – This study provides several implications for the policy debate on globalization and child labor and end by suggesting that rich countries should restrict the sale of goods from developing countries that lack or do not enforce child labor laws. Yet many doubt the ability of trade sanctions to eliminate child labor.

Originality/value – This could be the first ever effort in describing child labor incidence with the help of VAR technique for Pakistan.

Keywords International trade, Pakistan, Children (age groups), Labour market, Poverty, International investments

Paper type Research paper

1. Introduction

At the beginning of the twenty-first century, child labor remains a global problem of enormous proportions. A recent International Labor Organization (ILO, 2006) report reveals that in 2004 approximately 166 million children between the ages of 5 and 14 years were classified as child laborers accounting for about 14 percent of all children in this age group. In the same year, about 75 million child laborers between the ages of 5 and 14 years were engaged in hazardous work which can affect adversely the child's safety, health, or moral development. The child labor problem is particularly severe in the Asia-Pacific region and sub-Saharan Africa, where on average 19 and 29 percent of the children aged 5-14, respectively, are economically active. Although the report documents that over the period 2000-2004 the number of child laborers declined by 11 percent and the number of children in hazardous work fell by almost 33 percent,

JEL classification – I82, I30, F10, F16

International Journal of Social Economics
Vol. 35 No. 11, 2008
pp. 809-822

0306-8293
DOI 10.1108/03068290810905432

this encouraging trend is not satisfactory (ILO, 2004). In some countries, such as Mali and Bhutan, the labor force participation rate of children aged 10-14 reaches 50 percent. Child workers therefore account for a large fraction of the total work force in many developing countries (ILO, 2002a; World Bank, 2002).

In the case of Pakistan, out of the 40 million children 3.3 million children (in the 5-14 years age group) are economically active on a full-time basis. Of the 3.3 million working children, 73 percent were boys and 27 percent girls. Children's contribution to work in rural areas is about eight times greater than in urban areas. The number of economically active children in the 10-14 years age group is more than four times the children in the 5-9 years age group. 74 percent of children are mostly engaged in the agricultural sector in rural areas, whereas 31 percent of working children are engaged in the manufacturing sector in urban areas. In both areas, the percentage of girls working in manufacturing and services is higher than that of boys; this indicates that girls are more likely to work in the manufacturing and services sectors as compared to boys. It is also observed that in the non-agricultural sectors, most of the working children (93 percent) are engaged in informal activities (Federal Bureau of Statistics, 1996).

Furthermore, there is a significant body of literature on the economics of child labor, the international economics of child labor remains in its infancy[1]. Relatively speaking, only a few studies have formally addressed the link between globalization[2] and child labor. Much of the recent policy debate and controversy surrounding globalization and the WTO has been focused on the issue of child labor in poor countries. On one hand, opponents of market integration argue that globalization may increase the wages paid to working children or increase the earnings opportunities of children in poor economies, thereby increasing child labor (Bhatwati, 1995; Maskus, 1997)[3]. Trade liberalization in a developing country, which is abundant in unskilled labor, will not only have a substitution, but also an income effect which will raise the relative rate of return of unskilled labor (Rodriguez and Rodrik, 2000). This income effect can be expected to reduce the incentive for parents with little skills to send their children to work if we assume that child leisure and child education are normal goods and second is the incentive/substitution effects arise from changes in the present and future wages of a child that change the opportunity costs and returns to education (Grote and Weinhold, 1998; Ranjan, 2001; Jafarey and Lahiri, 2002).

Edmonds and Pavcnik (2004) conclude that trade openness might lower child labor, but only via its positive effect on *per capita* income[4]. Basu and Chau (2004) analyze the effects of trade openness in a dynamic model of child labor and debt bondage. Trade openness increases the short-run supply of child labor but does not affect the long-run incidence of child labor. The existing empirical work in a cross-country setting documents a negative association between openness and child labor (Shelburne, 2001; Cigno *et al.*, 2002).

Regarding the link between foreign direct investment (FDI) inflows and child labor, Cooke and Noble (1998) found a positive and statistically significant relationship between FDI and child labor. Given the high policy relevance of the topic, it is rather surprising that only a few studies have so far come up with empirical evidence on the link between child labor and FDI. Kucera (2002) concludes that the level of child labor is not an important location criterion for foreign investors, Busse and Braun (2004) find a statistically significant negative relation between child labor and FDI. Apart from these empirical studies, there is some anecdotal evidence of international

linkages between the use of child labor and trade/investment (Bales, 2000; Brown, 2000).

Despite the fact that most of the developing economies have adopted free trade as their development strategy, empirical evidence suggests that in many of the transition economies the incidence of child labor has been on the rise (Basu, 2002). Theory work on child labor emphasizes the importance of poverty (Basu and Van, 1998) or phenomena associated with poverty such as credit constraints (Baland and Robinson, 2000; Ranjan, 2001) as determinants of high levels of child labor and low schooling rates in poor countries[5]. Labor demand conditions also play a role (Basu and Van, 1998; Maskus, 1997; Brown, 2000; Dixit, 2000; Ranjan, 2001). Shelburne (2001) identifies a negative relationship of child labor with country size, *per capita* GDP, and a country's openness. Cigno *et al.* (2002) also propose a static estimate and identify a significant negative impact of country trade openness on child labor.

Child labor is more prevalent in rural than in urban areas. In rural areas, there is more agricultural activity, which is one of the main sectors of child employment, often on commercial plantations and without any form of payment (Ahmed, 1999; ILO, 2002b). The educational system is likely to be of poorer quality and enforcement of school attendance regulations and child labor bans is likely to be lax. Also, parents in urban areas tend to be more educated, which spurs an interest in the education of their children. Rural households on average are poorer than their urban counterparts (Edmonds and Pavcnik, 2002). Furthermore, social and cultural norms are more traditional in rural areas leading to a higher social acceptability of child labor.

The phenomenon of child labor has been viewed as an epidemic of the global economy that must be eventually eliminated. Thus, analyzing the economic effects of globalization on the incidence of child labor constitutes high research and policy priorities. The successful elimination of child labor throughout the world is probably one of the most important policy objectives of our time. The bulk of the literature on child labor is focussed on the determinants of child labor, supposedly because knowing the determinants is essential for establishing policy targets and instruments to combat child labor.

The present study aims to examine the implications of factors (FDI, openness, GDP *per capita*, share of agriculture in GDP and urbanization) on the incidence of child labor in a general equilibrium setup. The methodological framework for causality testing is a multivariate vector autoregression (VAR) model. This permits us to investigate the importance of factors on the incidence of child labor in Pakistan. More generally, this study seek to establish the causal link between these factors and child labor, which might suggest important implications for eradicating child labor's strategies for Pakistan

Section 1 of the paper presents the child labor situation in Pakistan. Section 2 presents the empirical model. Section 4 presents the estimated results, Section 5 concludes with some policy recommendations and Appendix section discusses the estimation techniques and data.

2. The empirical model

This section incorporates child labor in a standard general-equilibrium model of a small open economy facing perfectly competitive markets and a free-trade policy. Several theoretical papers address the relationship between trade policy

and child labor in developing economies that are relatively abundant in unskilled labor. Trade policy affects the prices of a product produced by child labor (or adult labor), thus influencing the allocation of child time. Greater openness to trade is seen both as one of the causes of child labor problems worldwide and as a potential cure for them. Globalization critics often blame international trade for setting new incentives for child labor abuse. In contrast, many economists believe that gains from trade can make a powerful contribution to eradicating child labor. However, while the average income effect always reduces child labor, reductions in inequality can also raise child labor (Rogers and Swinnerton, 2001).

In the light of discussion in Section 1, following model is formulated to determine the impact of globalization (represented by increased FDI, export and import), urbanization, agriculture growth and poverty on the incidence of child labor in Pakistan

$$CL_t = f(FDI_t, OPN_t, PGDP_t, AGI_t, URPOP_t) \quad (1)$$

where, FDI_t, FDI inflows (as percent of GDP); $PGDP_t$, log of GDP *per capita*; OPN_t, trade openness (the ratio of the sum of exports and imports to GDP); AGI_t, value added by agriculture sector (as a share of GDP); $URPOP_t$, urbanization (share of urban population in total population); CL_t, child labor (labor force participation rate of 10-14 year old children; t, time period (i.e., 1970-2003).

To empirically estimate model 1 multivariate causality approach is followed. Many tests of causality have been derived and implemented, including (Granger, 1969; Sims, 1972; Geweke, 1982; Hamilton, 1994). It is quite straightforward to test for the direction of causality between two or more given variables. For investigating the linear relationship between macroeconomic variables (Engle and Granger, 1987; Johansen and Jusellius, 1990), a cointegration test is performed. The procedure adopted is the Johansen and Jusellius (1990) method, which was designed to examine the restrictions imposed by cointegration on the unrestricted VAR model. The VAR model is estimated with maximum likelihood framework and has the advantage of allowing the joint determination of CL_t, FDI_t, AGI_t, $LPGDP_t$, OPN_t, and $URPOP_t$. Moreover, it takes into account the short-run dynamics of the variables, while permitting the system of variables to return to their long-run steady-state equilibrium level.

As argued by Granger (1969), standard Granger causality tests are invalid if the time series are nonstationary. Further, if cointegration is established, then a vector ECM, or cointegrated VAR, should be used to investigate causality. The advantage of VECM as opposed to the unrestricted VAR is that the information in about the long run is retained in the cointegrating combinations, and the stationarity properties of the variables involved in the system are properly taken into consideration (Johansen, 1991; Johansen and Katarina, 1992).

The mathematical version of multivariate causality model is given in the Appendix.

The empirical results reported in this study are based on data collected for the following variables: Child Lbour (10-14 years of age), GDP *per capita* (PGDP), FDI, exports (EX), imports (IM), value added by agriculture sector as share of GDP (AGI), and urbanization (URPOP). Additionally, we construct a measure of trade openness OPN = (EX + IM)/GDP) as a substitute for exports and imports. The data set used is annually and covers the period 1970-2003. All data are extracted from World Development Indicators (WDI, 2005).

3. Empirical results

Table I gives the results of ADF unit root tests. The null hypothesis of a unit root is not rejected for any of the level variables. The results indicate that variables are integrated of order 1 suggesting that the analysis should proceed to cointegration and error correction model to tests short-run relationships between specified variables. In estimating the long-run relationship among the variables, both maximum eigenvalue and trace test statistics are applied to determine the number of cointegrating vector among the variables. This study employed the AIC and SC values with lag lengths chosen by downward search (AIC and SC) to determine the VAR lag length and choose the two lags for carrying the Johansen test. Table II presents the cointegration results based on the trace test and eigen values which shows that the null hypothesis of no-cointegration is rejected at 1 percent significant level. Cointegration test indicate that there is at most five cointegrating vectors (rank = 5) in the system. It can be seen that cointegrating combination exists between child labor, FDI, openness, value added by agriculture as share of GDP, *per capita* GDP and urban population. The results therefore provide the strong evidence of the long-run causality among all said variables, which implies that all variables included in the system adjust in significant fashion to clear any short-run disequilibrium.

Cointegarting normalized coefficients are also used to measure the magnitude of the long-run causality among variables. The estimated coefficients of the cointegrating vector are shown in Table III. The estimated coefficients of explanatory variables are

	Level		First difference	
Variable	Intercept	Trend	Intercept	Trend
CL_t	3.85	0.61	−2.24	−4.65*
FDI_t	−1.63	−2.69	−5.21*	−5.12*
OPN_t	−2.47	−1.98	−4.84*	−5.07*
$LPGDP_t$	−1.74	−2.82	−4.86*	−5.66*
$URPOP_t$	−1.28	−1.99	−6.86*	−6.99*
AGR_t	−1.27	−2.25	−5.33*	−5.56*

Notes: Critical values are: −3.61, −2.94, −2.61 (significant at 1, 5, and 10 percent, respectively, when first difference is constant), and −4.22, −3.53, −3.21 (significant at 1, 5, and 10 percent, respectively, when first difference is constant and trend). *, **, *** represent significance at 1, 5 and 10 percent, respectively

Table I.
ADF test

	Maximal-Eigen test	5 percent critical value	1 percent critical value	Trace test	5 percent critical value	1 percent critical value
$R = 0$	76.45*	27.59	28.17	225.60*	141.9	124.75
$R \leq 1$	53.09*	24.32	26.53	149.15*	87.31	96.58
$R \leq 2$	41.72*	20.55	21.6	96.06*	62.99	70.05
$R \leq 3$	28.34*	17.12	18.0	54.34*	42.44	48.45
$R \leq 4$	18.01*	13.07	14.19	26.00*	25.32	30.45
$R \leq 5$	7.99*	12.25	16.26	7.99	12.25	16.26

Notes: *Rejection of the hypothesis at 5 percent(1 percent) significance level. LR test indicates five co-integrating equation(s) at 1 percent significance level

Table II.
Johansen co-integration test

found significant at 1 percent level. The results, confirm that openness and the urban population have a positive and significant impact on child labor, while the agriculture share in GDP and FDI significantly contributes to reduce child labor. It has been argued that agriculture sector play an important role in promoting child labor, particularly if the child comes from poor and rural areas. This study found that the effect of AGI_t on child labor is negative and statistically significant which is surprising in a sense because 70 percent Pakistani population is engaged in agriculture sector at traditional perspective. The explanation may be that some incidence of child labor has shifted from rural to urban areas due to huge urbanization and trade liberalization which gives most favorable wages and employment opportunities to the unskilled child labor. This study suggests that families in the urban areas found more opportunities to put their children to work than families in rural areas. It is also the case that many of the children that worked in rural areas were initially pauper apprentices with little say in how much they worked or what compensation they received. Our positive and significant coefficient of urban population also provides the support for the above argument that is incidence of child labor is increasing with urbanization. So the negative association between AGI_t and CL_t may prove through positive involvement of urbanization with child labor for this study.

The present study founds that openness (OPN_t) is positively and significantly related to child labor. The possible explanation is that trade liberalization raises the output of the exportable sector (as discuss in Section 1) and increases the demand for child labor as well as the child-wage. Openness of market integration argue that globalization may increase the wages paid to working children or increase the earnings opportunities of children or in poor economies, thereby increasing child labor. So the effects of openness also strongly support the negative impact of agriculture sector on child labor.

As far as FDI is concern, foreign investors seem to be less interested in exploiting unskilled labor than is presumed by the conventional wisdom due to the fact that market size and market growth, political stability, and infrastructure are often as important, if not more important, than low wages. Our results are consistent with the findings of earlier studies conducted by Rodrik (1996) and Kucera (2001, 2002).

Theory tells us to expect a correlation between income and child labor under a couple of different circumstances. On one hand, if a quality child is a normal good, then there should be a straightforward negative correlation between income and child labor. On the other hand, if credit-constrained then parents used their children as a source of transfer income from the future into the present. In this case, the desire to reallocate income backward through time will occur only if current income is lower than expected future income. Thus, child labor responds not to the level of income today, but rather to

AGI	FDI	LPGDP	OPN	URPOP	Trend	*C*
CL						
− 0.184	− 0.196	0.176	4.956	0.019	− 0.429876	− 29.65
(0.007)	(0.066)	(0.281)	(0.504)	(1.176)	(0.022)	
(26.2*)	(3.0*)	(0.63)	(9.848*)	(0.11)	(19.5*)	

Table III.
Co-integrating coefficients normalized on CL

Notes: *Significant at 1 percent. Numbers in parenthesis are standard error and *T*-statistics, respectively

the level of income today relative to future income. The empirical findings of this study document the positive but insignificant impact of the *per capita* GDP on child labor because as argued by Baland and Robinson, child labor is a device for transferring resources from the future into the present. Children who work do not invest in human capital that would make them more productive in the future. A family will choose to make this intertemporal shift in household resources when current income is low relative to future income. Thus, it is not the absolute level of family income that matters for the child labor decision but, rather, the current level relative to future income.

In order to examine the predictive abilities of different time series in the model, a Granger causality test is applied after cointegration method. We employ test for Granger causality by using the VECM. Accordingly, VECM is estimated, not only to assess the causal relationship but also to gauge the speed of adjustment towards equilibrium.

Table IV reports the result of VECM formulation. According to Engle and Granger (1987), co-integrated variables must have in ECM representation. Technically, the error correction term (ECT_{t-1}) measures the speed of adjustment back to the co-integration relationship. The ECT_{t-1} posited to be a force causing the integrated variables to return to their long-run relation when they deviate from it, and thus the longer deviation; the greater would be the force tending to correct the deviation (Banerjee *et al.*, 1994).

The coefficients on the lagged values of ΔCL_t,$\Delta AGI_{t,}\Delta FDI_{t,}\Delta LPGDP_t$,$\Delta OPN_t$ and $\Delta URPOP_t$ are short-run parameters measuring the immediate impact of independent variables on dependent variables. This study founds no Granger causality between child labor and all lagged independent variables in the short run. The present study also found no any Granger causality of AGI_t and FDI_t for its all lagged independent variables in the short run. However, this study found that the lagged variable of openness and urban population causing *per capita* GDP in the short run. FDI_t and $LPDGP_t$ have Granger causality for the equation of openness. For the equation of urban population the *F*-statistics of lagged value of all independent variables are statistically significant showing their impact on urban population in the short run.

Although we do not detect any short-run causality among the variable but the value of ECT_{t-1} (the error correction term in almost all the equations) are found to be statistically significant suggesting existence of powerful long-run causality running from independent variables to dependent variables as discussed by King *et al.* (1991). Hence, it can be concluded that the models itself are converging into the long-run equilibrium.

4. Conclusions and policy implications

The paper investigated potential impacts of international trade on child labor that is motivated by subsistence needs. Study review some of the evidence found in those countries that are more open towards trade and are more penetrated by FDI and display a lower incidence of child labor. It also provides empirical evidence on the relationship between market integration (or globalization) and the incidence of child labor in poor, relatively unskilled labor-abundant economies.

This paper has conducted Granger causality tests across a variety of specifications within a VAR/VECM framework. The main contribution of the paper is that it identifies causal links among factors affecting and affected by child labor in Pakistan.

Table IV.
ECM model

	F-statistics for $\sum\Delta CL_{t-i}$	F-statistics for $\sum\Delta AGI_{t-j}$	F-statistics for $\sum\Delta AGI_{t-k}$	F-statistics for $\sum\Delta LPGDP_{t-l}$	F-statistics for $\sum\Delta OPN_{t-m}$	F-statistics for $\sum\Delta URPOP_{t-n}$	T-statistics for ECT_{t-1}
ΔCL_t	–	0.29	1.30	0.74	1.42	1.11	-1.03
ΔAGI_t	1.06	–	1.36	0.97	0.64	0.34	-1.80^{***}
ΔFDI_t	0.65	0.28	–	1.79	0.28	0.60	-2.82^{**}
$\Delta LPGDP_t$	2.09	1.27	1.01	–	2.72^{***}	2.87^{***}	-3.09^{*}
ΔOPN_t	0.79	2.39	3.05^{***}	2.81^{***}	–	1.69	-2.96^{**}
$\Delta URPOP_t$	2.84^{***}	3.43^{**}	3.19^{***}	2.67^{***}	2.70^{***}	–	-2.97^{**}

Note: *, ** and ***denotes significant at 1, 5 and 10 percent, respectively

The empirical analysis has involved, after testing the integration and cointegration properties of the data, investigation of causality links between variables. The main issue here has been to ensure that causality inferences drawn for the empirical analysis are robust with respect to changes in the VAR/VECM specifications.

Summing up the empirical evidence, for Pakistan foreign investors seems to be less interested in exploiting cheap labor, including that of child laborers, than is presumed by the conventional wisdom. Our result is consistent with the empirical studies conducted by Rodrik (1996) and Kucera (2001, 2002) which also fails to find that countries with low labor standards in general and a high incidence of child labor in particular attract a greater inflow of FDI. For openness study conclude that it is found to be raising the output of the exportable sector and increasing the demand for child labor as well as the child-wage. The effects of openness also strongly support the negative impact of agriculture sector on child labor. Poverty also found to be supporting the view that to take advantage of higher income opportunities parents send their children to work.

Although study do not provide evidence of FDI increasing incidence of child labor but positive effect of openness to trade on child labor provides several implications for the policy measures. For example, the increased earnings opportunities associated with globalization found to be attracting children towards work in export-oriented sectors (indicated by positive coefficient of openness of trade) thus leading to higher incidence of child labor. In the present case, households appear to have taken advantage of higher price. To earn more they have started sending children to work. Many globalization opponents and trade policy-makers advocate that higher income countries employ trade sanctions to force domestic policies in poor countries to eradicate child labor. So, these trade measures would likely lower the price of the exported goods in near future. On the basis of our results we suggest that these sanctions should properly be investigated and implemented to reduce the incidence.

An effective policy against child labor is to promote the development of functioning credit markets in developing countries and to facilitate the access to these markets for poorer households. With access to capital markets, parents will arguably allocate more of their children's time to education, since they will be able to shift wealth from the future to the present by borrowing against future income. In contrast, the absence of functioning credit markets leaves the parents without any choice but to put children at work and results in inadequate human capital formation.

From a policy perspective, child labor that is compelled by poverty has a special role: As long as the child's earnings are needed for subsistence of the family, a policy intervention can only be successful if it raises the current income of the poor (be it by redistribution, credit provision or other means). Thus, the paper complements the existing theoretical literature on child labor in an open economy setting, without questioning the importance of other explanatory factors for child labor besides poverty constraints.

We end by suggesting that rich countries should restrict the sale of goods from developing countries that lack or do not enforce child labor laws. Yet many doubt the ability of trade sanctions to eliminate child labor. As several studies analyzing the role of trade sanction in eliminating child labor have provided ambiguous evidence on the effect of trade sanction on lowering incidence of child labor. For example, Gupta (2002) conclude that trade sanctions may raise the welfare of a country using child labor by

reducing unemployment in the adult labor market. However, this does not necessarily reduce the supply of child labor. Ranjan (2001) shows that in a world with credit constraints trade sanctions may fail to reduce the incidence of child labor, as they lead to a decline in income of parents who are unskilled. Jafarey and Lahiri (2002) also demonstrate that the impact of trade sanctions on the incidence of child labor crucially depends on the working of credit markets. Child labor is more likely to be reduced by trade sanctions when poor families have better access to credit. The general equilibrium model of Bandyopadhyay and Bandyopadhyay (2005) incorporates a non-tradable sector. They find that the effect of trade sanctions on child labor critically depends on the pattern of substitutability between the service sector and the exportable sector.

Notes

1. Closed-economy models of child labor include Basu and Van (1998), Basu (2002), Genicot (2005) and Doepke and Zilibotti (2005) among others. Basu (1999) and Brown *et al.* (2001) provide comprehensive surveys of the growing strand of child-labor literature.
2. Globalization is the process by which an increasing share of world production is traded internationally, and the productive systems of different countries become increasingly interdependent.
3. Maskus (1997) provides an overview of the broader literature on international trade and labor standards.
4. While their central focus is on credit constraints, Deheija and Gatti (2002) similarly find no relationship in one of their estimations between export and import openness on the labor participation rate of children aged between 10 and 14 years.
5. See Basu (1999) and Basu and Tzannatos (2003) for surveys of theory work on child labor.
6. In our case $X_t = (OPN_t, FDI_t, PGDP_t, AGI_t, UBPOP_t)$.

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Appendix. Estimation technique

Following Johanson (1988) and Johansen and Jusellius (1990) consider the following VAR model.

Let $\mathbf{X}_t$ denote a vector of time series[6]:

$$\mathbf{X}_t = (X_{1t}, X_{2t}, \ldots, X_{nt}); \quad n > 2 \tag{A1}$$

in which all the $\mathbf{X}_t$ are assumed to be $I(1)$. This vector admits a representation as an autoregressive VAR(p):

$$\mathbf{X}_t = \mathbf{\Phi}_1 \mathbf{X}_{t-1} + \cdots + \mathbf{\Phi}_p \mathbf{X}_{t-p} + \boldsymbol{\mu} + e_t \tag{A2}$$

with:

$$e_t \sim I \cdot N(0, \mathbf{\Omega})$$

and where $\boldsymbol{\phi}_t$ represents a matrix of parameters $n \times n$, $\boldsymbol{\mu}$ a vector of constants and $\mathbf{\Omega}$ the matrix of covariances. This system can be represented as a system of error correction (VECM):

$$\Delta \mathbf{X}_t = \sum_{i=1}^{p-1} \Gamma_i \Delta \mathbf{X}_{t-1} + \mathbf{\Pi} \mathbf{X}_{t-p} + e_t \tag{A3}$$

or, more generally, accepting the existence of a trend $\boldsymbol{\mu}$ and exogenous variable $I(0)$: Z_t it may be:

$$\Delta \mathbf{X}_t = \boldsymbol{\mu} + \Gamma_1 \Delta \mathbf{X}_{t-1} + \cdots + \Gamma_{p-1} \Delta \mathbf{X}_{t-p+1} + \mathbf{\Pi} \mathbf{X}_{t-p} + \gamma \phi_t + \varepsilon_t \tag{A4}$$

All the differenced $\mathbf{X}$ vectors will be made up of $I(0)$ variables; hence the n linear combinations of the variables $\Gamma_p \Delta \mathbf{X}_{t-p}$ must also be $I(0)$, even if the original variables composing them were $I(1)$. Given that $\mathbf{X}_t$ is made up of n variables, the dimension of Γ is $n \times n$ and its rank equal to or less than n. In fact, the rank of $\mathbf{\Pi}$ will coincide with the number of linearly independent cointegration vectors which might exist among the n variables of $\mathbf{X}$. If this number is assumed to be $r (r < n)$, it will be possible to define a matrix $\boldsymbol{\beta}(n \times r)$, such that its columns are the cointegration vectors. That is:

$$\boldsymbol{\beta}' \mathbf{X}_{t-p} \sim I(0) \tag{A5}$$

and it will also be possible to construct a matrix $\boldsymbol{\alpha}(n \times r)$, in which these will be contained in rows, the ratios with which the different cointegration relationships of the system enter in each equation. That is:

$$\boldsymbol{\alpha} \boldsymbol{\beta}' = \mathbf{\Pi} \tag{A6}$$

So, on the basis of these matrixes α and β, the equation could be expressed:

$$\Delta \mathbf{X}_t - \boldsymbol{\alpha} \boldsymbol{\beta}' \mathbf{X}_{t-p} = \Gamma_1 \Delta \mathbf{X}_{t-1} + \cdots + \Gamma_{p-1} \Delta \mathbf{X}_{t-p+1} + e_t \tag{A7}$$

where $\Delta \mathbf{X}_t$ and $\mathbf{X}_{t-p}$ can be substituted by the residuals which may result from the regression of each of them with regard to the $\Delta \mathbf{X}_{t-1}, \ldots \Delta \mathbf{X}_{tp+1}$, denominated R_{ot} and R_{pt}, respectively. Thus, the last equation is left:

$$R_{ot} - \boldsymbol{\alpha} \boldsymbol{\beta}' R_{pt} = e_t \tag{A8}$$

the likelihood function of which is L ($\boldsymbol{\beta}$, $\boldsymbol{\alpha}$, $\mathbf{\Omega}$). Once $\boldsymbol{\beta}$ is known, $\boldsymbol{\alpha}$ and $\mathbf{\Omega}$ can be estimated, by means of an R_{ot} regression on $\boldsymbol{\beta}' R_{pt}$. Johansen shows how to estimate $\boldsymbol{\beta}$ by finding certain auto values and their corresponding autovectors. Nevertheless, the parameters $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are not identified; and, in fact, any normalization of the corresponding matrices will be equally valid, hence the chosen normalization must be duly justified. Moreover, and in order to determine the

number of cointegration vectors, Johanson (1988) proposes a test based on a Likelihood ratio derived from the eigenvalue of the stochastic matrix and the Trace of this matrix. Short-term elasticities are estimated by calculating the residual and regressing it on the lagged differenced variables and the covariables:

$$R\mathbf{X}_t = \Delta\mathbf{X}_t - \hat{\Pi}_{\mathrm{MV}}\mathbf{X}_{t-p} \tag{A9}$$

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