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**DIRECT AND INDIRECT CAUSALITY BETWEEN EXPORTS AND
ECONOMIC OUTPUT FOR BANGLADESH AND SRI LANKA:
HORIZON MATTERS**

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Abstract

The extensive body of research that examines for (Granger, 1969) causality from exports to output for developing countries, including Bangladesh and Sri Lanka, using vector autoregressions and/or vector error correction models, is limited in only examining for one-period ahead or direct causality; the exception is in bivariate systems. This (usually unrecognized) focus on one-period causality in multivariate systems has often led to conclusions that exports do not Granger-cause economic output. We show that moving to Granger-causality at longer horizons, in a commonly used multivariate system, leads to bidirectional causality between exports and output, even when there is not one-period causality; the longer horizon causality arises indirectly through one or more of the auxiliary variables.

Keywords: Economic growth; Granger causality; export-led growth; vector autoregressions

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1. Introduction

There exists a large literature on examining for export-led growth (ELG) using Granger's (1963, 1969) concept of causality, which builds on that proposed by Wiener (1956); e.g., the survey of Giles and Williams (2000a, b) reports on nearly seventy such studies. The focus is often on developing or newly industrializing countries, including Bangladesh and Sri Lanka, who have been forwarding their economic development and opening their economies. As expansion of the export sector is often hypothesized to assist advancement, for example from productivity gains by learning through exporting (e.g., Blalock and Gertler (2004)), researchers have sought to ascertain whether sample data is supportive of this view.

The vector autoregression (VAR) model and its equivalent representation, with integrated and cointegrated series, the vector error correction model (VECM), are fundamental to these explorations. Irrespective of which model is adopted, the ELG studies examine for Granger causality as a test of exact linear restrictions on the coefficients with, usually, a Wald statistic; sample compatibility with the restrictions under the null hypothesis leads researchers to conclude that export-led growth has not been a feature (i.e., support for the notion of noncausality, denoted as NC), while a finding of ELG (i.e., Granger-causality, denoted as GC) is reported when the restrictions under the null are rejected. Two other causal concepts are also studied: growth-led exports (GLE), when the sample suggests that output causes exports, and bidirectional causality (BDC), which corresponds to feedback between exports and economic output. Policy recommendations, and comments on the success of economic strategies, often follow; for example, Love and Chandra (2004, p. 494) conclude "*The evidence that export growth has a beneficial impact on income growth is particularly heartening ... An export-led-growth strategy as a future course of action...can pay rich dividends ...*"

Evidently, empirical results are ambiguous with no consensus on the causal relationship between exports and economic output. As we detail in the next section, researchers have reported the full gambit of causal outcomes (NC, BDC, ELG and GLE) for Bangladesh and Sri Lanka. Different sample periods, model specifications, including regressor sets, and treatment of issues related to integration and cointegration, are likely contributing factors. Some studies have stressed such concerns. Love and Chandra (2004, p.485), for example, claim to contribute to the export-led growth debate in South Asian countries by being "*the first of its kind which adopts a multivariate framework...(and)...it seeks to correct the misspecification bias of earlier studies by including the terms of trade as a relevant variable*", and Arnade and Vasavada (1995) and Islam

(1998), amongst many other others, adopt the use of VECMs, rather than VARs in the first differences of the levels of the variables under study, as they recognize that such differenced VARs suffer from the omission of terms in the presence of cointegration. In addition, Monte Carlo simulations have been undertaken to show the distortions on Type I error probabilities for the Wald statistic for Granger noncausality that can arise from the strategies commonly employed – Clarke and Mirza (2005, p.1), for example, report, on the basis of their simulation experiments, “*We find that the practice of pretesting for cointegration can result in severe over-rejections of the noncausal null...*”; this arises because the commonly used pretests for the cointegrating rank are not themselves reasonably accurate.

A major concern with the multivariate studies, the exploration of which may lead to consensus on causal dynamics, is that lack of support for ELG, as traditionally tested for, is only lack of evidence of one-period ahead, or direct, causality; causality from exports to economic output, arising indirectly at longer horizons, via the other macroeconomic variables in the system, remains feasible and should be considered. Similar comments apply for direct and indirect causal relationships between other variables in the system. Pertinent, general, theoretical discussions and developments are provided in: Sims (1980), Dufour and Renault (1998), Renault et al. (1998), Giles (2002) and Dufour et al. (2005); see also Giles and Williams (2000a) for a relevant ELG discussion, although these authors do not test for indirect causality in the applications provided in Giles and Williams (2000b).

We examine for direct and indirect causality between exports and economic output for Bangladesh and Sri Lanka in a four-variable VAR system; the auxiliary variables are terms of trade adjustment and gross capital formation. In contrast with the empirical literature we report on, we remain within the levels VAR framework to obtain test statistic sample values, given the simulation evidence that suggests the common VECM route for obtaining Wald test statistics for Granger noncausality can lead to over-rejections of the null hypothesis; we use the approaches of Toda and Yamamoto (1995), Dolado and Lütkepohl (1996) and Choi (2005) to accommodate that the variables may be integrated and cointegrated.

Evidence is presented for one-period or direct ELG for Bangladesh and NC for Sri Lanka. More importantly, for economic development in these countries, significant bidirectional causality is detected between exports and national output at higher horizons for both countries; i.e., indirect bidirectional causality or feedback between exports and economic output arises, even when the usual, direct, one-period test suggests unidirectional causality or noncausality. Such outcomes highlight the importance of the horizon, with indirect impacts via auxiliary variables, when testing for causality.

This paper is organized as follows. Section 2 briefly details some background information on Bangladesh and Sri Lanka, including the relevant empirical literature on testing for Granger-causality between exports and economic output. We detail our modeling framework and the relevant econometric techniques for testing for direct and indirect Granger noncausality in Section 3. Data descriptions and summary statistics are provided in Section 4, as well as discussion on some further, needed, modeling issues. The results are presented in Section 5, followed by concluding remarks in Section 6.

2. Background

Various positions are advocated on the debate of the merits of developing countries adopting export-led growth strategies, or, perhaps more accurately, between outward- and inward-looking strategies of development. Import substitution strategies of development dominated in the 1950s and 1960s, whereas export expansion was the focus in the late 1970s and, especially amongst Western and World Bank economists, in the 1980s and 1990s. Recently, some have argued more strongly that countries need to focus more on domestic development with government intervention, along with a more controlled role for liberalization in development; e.g., see, Rodrik (1992, 2001), Lall (2004).

Efficiency and growth benefits from trade and competition, access to larger world-markets leading to increases in real output, specialization in production that raises productivity and skills, reallocation of resources from inefficient, domestic sponsored, markets to (more) efficient export sectors, removal of distorting price and cost effects of protection, knowledge advancement from exposure to export markets, transfer of technology, attraction of foreign capital and expertise, generation of foreign exchange for needed imports, are some of the many reasons advocated by proponents of export promotion. In addition, the East Asian economies – South Korea, Taiwan, Singapore, Hong Kong and, more recently, China and India – are often cited as examples of export-led growth countries for others to follow.

Proponents of inward-looking development suggest that each developing country needs to develop in a manner appropriate to its own endowments – protectionism to ensure self-reliance. Protection is advocated to enable advancement via “learning by doing” in manufacturing and technology, without the need to simultaneously compete with external countries. This results in greater domestic industrial diversification, so perhaps leading to a more balanced growth, with the domestic economy less affected by turbulence and unpredictability in external markets. Such a strategy is cited as leading eventually to lower domestic prices, and development to a stage ready to compete externally. Furthermore, many of the global markets, to which the developing

nations can target, are themselves often protected, making it difficult for the developing nation to compete for market share.

In reality, many countries, including Bangladesh and Sri Lanka, sequentially, and simultaneously, promote export expansion and trade liberalization with intervention and protection. Indeed, the East Asian tigers pursued protectionist strategies in addition to export promotion strategies, with their governments more interventionist in the development of agriculture, industry and education than might initially seem to be the case. For instance, South Korea, now classified by the World Bank as a high-income economy, pursued major export promotion-oriented policies in the years of its rapid development, alongside an extensive system of import controls that effectively protected infant industries, as well as imposing stringent local content rules and creating support industries. Taiwan, who has essentially eliminated absolute poverty, with low unemployment, high life expectancy and only a modest relative inequality scale, emphasized education, infrastructure development, land reform, high rates of savings and investment, along with export promotion and active government intervention (e.g., controlling direct foreign investment and categorizing imports into those which were “prohibited”, “controlled” and “permitted”). See, for example, Bradford (1986), Luedde-Neurath (1986), Lall (1996) and Wade (1990).

The pursuit of such policies by Bangladesh and Sri Lanka, along with the reforms and developments that have taken place, some of which we briefly detail in the next sub-sections, suggests we might expect to detect bidirectional causality between exports and GDP, particularly once we allow for indirect causality via auxiliary variables.

2.1 Bangladesh

This populous country of approximately 144 million, dominantly Bengali Muslims, became independent from (West) Pakistan in 1971, having formerly been East Pakistan when independence from Britain was granted in 1947. With over three-fifths of the population involved in farming, agricultural production contributes close to 30% of GDP, primarily from rice, jute, tea, sugar and wheat, while only approximately 15% of GDP is generated from manufacturing (e.g., garments and knitwear, fish, jute goods, leather and leather products, ceramics, chemicals). Exports of goods and services has increased from approximately 5% of GDP in the mid-1980s to closer to 15% today, and the contribution of imports of goods and services to GDP has changed, over the same period, from approximately 13% to 20%. Savings and investment have also substantially increased their share of GDP over this time span.

Although Bangladesh governs as a parliamentary democracy, political infighting, weak governance, pervasive corruption and a relatively dysfunctional banking system have caused severe problems in development. Despite such issues, Bangladesh has devoted considerable effort to meeting the food needs of its poor via imports in addition to expanding domestic production. Bangladesh historically adopted import-substitution policies, using tariffs combined with non-tariff barriers such as import duties, while the pursuit of an open-door policy has recently taken front stage with a steady liberalizing of its trade regime (e.g., reduction in tariffs, removal of quantitative restrictions, simplifying import procedures) and a focus on improving export incentives.

In the early 1970s, over 90% of export earnings came from jute, followed by tea and leather; the country is the largest exporter of jute and jute products in the world. Since then, the country has broadened its export base to include ready-made garments, shrimp, fish, newsprint, chemical fertilizer, ceramic products; the growth in ready-made garments, which now accounts for more than three-fourths of all exports, notably to foreign buying houses in India and Sri Lanka, has accelerated development over the 1990s, creating many new jobs for mostly women. The U.S. receives approximately 32% of Bangladesh's exports, followed by many European countries, whereas most of Bangladesh's imports arrive from India and other Asian countries, including China, Japan and Singapore.

Advancement of exports, in Bangladesh, is under the auspices of the Export Promotion Bureau, with foreign investment being highly sought after in the export-oriented industries such as textiles, leather goods, electronic products & components, and chemicals. That an export led-growth philosophy is being pursued is evident from, for example, the Export Promotion Bureau's latest Export Policy¹, 2003-2006, which links export expansion to employment opportunities, increasing savings and investment, eradicating poverty, and reaching goals in national growth.

Despite the aforementioned difficulties, focus on development in other areas, aside from those involved in exporting, has taken place. Significant growth has occurred in savings and private sector investment, with the government slowly implementing policies to reduce resource waste by the public sector, including policies that aim to decentralize administration. Other efforts include reforms of the judicial and banking systems, as well as the operations of the stock market, improving transportation infrastructure, alleviation of poverty and empowerment of the poor, and human resource development. Protection and intervention strategies include cash subsidies for agro-processing, leather goods and light engineering; early protection for the

¹ See http://www.epb.gov.bd/export_policy.htm.

pharmaceuticals industry; imposition of import bans and restrictions; agricultural state trading monopolies; and average tariff rates that are usually higher than in other South Asian countries.

2.2 Sri Lanka

Sri Lanka (formerly Ceylon), a country of approximately 20 million, primarily Sinhalese, with small, but important, groups of Tamils and Muslims, became independent from Britain in 1948. Notwithstanding a democratic political structure, the country has suffered from political instability, with frequent elections impeding structural reform. Domestic unrest, most notably, the long civil conflict between the Sri Lankan army and the Liberation Tigers of Tamil Eelam (LTTE), has affected Sri Lanka politically, economically and socially, with development seen to crucially depend on maintaining cease fire accords and peace talks between the ruling Government and the LTTE.

Despite this trouble, Sri Lanka has been achieving an annual growth in real GDP around 5% per annum over the last decade, aside from a temporary downturn in 2001. The pace of change, however, has varied due to problems with macroeconomic management and a severe balance-of-payments crisis in the late 1980s. Agricultural production (rice, tea, rubber, coconut and spices), the service sector (tourism, transport, telecom, banking and finance) and industrial production (garments and leather goods, food processing, chemicals, refined petroleum, wood products) contribute, respectively, approximately 20%, 55% and 24% of GDP. Sri Lanka has one of the most open trade and foreign direct investment regimes in South Asia; e.g., foreign direct investment has played a crucial role in the clothing and tourism industries. Exports of goods and services, dominated by garments and footwear, tea², rubber products, jewelry and gems, refined petroleum and coconuts, have increased their share of GDP from approximately 25% in the mid 1980s to nearly 40% in recent times. The promotion and expansion of exports has been a feature of Sri Lanka's development since the establishment, in 1979, of the Sri Lanka Export Development Board. Their mission statement³ "*We facilitate the formulation and implementation of Sri Lanka's export strategy leading to national economic growth*" explicitly suggests the causal link of interest to us. The clothing industry has emerged as the country's main export earner, along with remittances from Sri Lankans working overseas.

The U.S. market is the major recipient country of Sri Lanka's exports, followed by the U.K., Germany, Japan and the United Arab Emirates. This growth in exports has been accompanied by rising imports of goods and services, primarily from India, Hong Kong and Singapore –

² Sri Lanka has now recaptured its position as the World's largest tea exporter with the successful privatization of the plantation sector.

³ See <http://www.srilankabusiness.com/tradepolicy/pdf/plan.pdf>.

expenditure on imports well exceeds that earned from exports. Various protection and intervention strategies have been pursued alongside the open trade regime, including tariffs on agricultural products; protection of the service sector (e.g., banking, telecommunications) and paper and metal products; royalties, duties and cesses on a range of natural-resource based products; and import duties have been used as a means of influencing the rate and direction of economic growth, in addition to being a source of revenue.

2.3 Causality studies

Using VARs or VECMs to examine for export-led growth, via Granger-causality, for Bangladesh and Sri Lanka has been popular. Salient details are provided in Table 1. Prior to the recognition in the literature that VARs in first differences might be misspecified, by omitting information from one or more cointegrating relationships, studies adopted the first difference VAR framework to detect Granger-causality: Jung and Marshall (1985), Bahmani-Oskooee et al. (1991), Hutchison and Singh (1992), Dodaro (1993), Love (1994) and Riezman et al. (1996) consider bivariate models, while Hutchison and Singh (1992), Sharma and Dhakal (1994), Abhayaratne (1996) and Riezman et al. (1996) provide results from multivariate first differenced VAR models; findings of BDC, NC, ELG and GLE are reported, depending on country, period of examination and the auxiliary variable(s) in the information set.

The move to bivariate and multivariate VECMs, in which to examine for noncausality, is made by Arnade and Vasavada (1995), Xu (1996), Islam (1998), Ekanayake (1999), and Love and Chandra (2004); cointegration is detected using procedures proposed by Engle and Granger (1987), Engle and Yoo (1987), Johansen (1988) and Johansen and Juselius (1990). Auxiliary variables in the multivariate systems include: real imports, in levels and as a share of gross domestic product; real investment, in levels and as a share of gross domestic product; terms of trade, defined as the unit value index of exports as a percentage of the unit value index of imports; and employment. Granger-causality results vary; e.g., Islam (1998), who detects cointegration, reports BDC for Sri Lanka and NC for Bangladesh in a 5-variable VECM, while Love and Chandra (2004) report NC for Sri Lanka.

Table 1
Summary information on export-economic output Granger-causality studies

Study	Bangladesh	Sri Lanka
Jung & Marshall (1985): bivariate VAR in first differences		NC
Bahmani-Oskooee et al. (1991): bivariate VAR in first differences		NC
Hutchison & Singh (1992): bivariate VAR in first differences		NC
trivariate VAR in first differences		NC
Dodaro (1993): bivariate VAR in first differences		NC
Love (1994): bivariate VAR in first differences		ELG
Sharma & Dhakal (1994): 4-variable VAR in first differences		NC
Arnade & Vasavada (1995): trivariate VECM	NC	NC
Abhayaratne (1996): trivariate VAR in first differences		NC
Riezman et al. (1996): bivariate VAR in first differences	GLE	ELG
trivariate VAR in first differences	NC	ELG
Xu (1996): bivariate VAR in first differences, no cointegration		GLE
Islam (1998): bivariate VECM	ELG	ELG
5-variable VECM	NC	BDC
Ekanayake (1999): bivariate VECM		BDC
Love & Chandra (2004): trivariate VECM		NC

Note. The acronyms are: ELG – export-led growth; GLE – growth-led exports; BDC – bidirectional causality or feedback; NC – noncausality

Several well-cited factors, such as the period under investigation and the chosen information set, likely contribute to the varying outcomes. In addition, how cointegration is detected usually has influence, as cointegration implies Granger-causality. Related, although less spoken of, is Monte Carlo simulation evidence (e.g., Toda and Phillips, 1994; Dolado and Lütkepohl, 1996; Zapata and Rambaldi, 1997; Clarke and Mirza, 2005) suggesting severe distortions in Type I error probabilities, from that expected, can arise for Granger noncausality tests after pretests for cointegration, as commonly applied by those who use the VECM route. Finally, of importance and ignored until this study, the multivariate studies to date examine only for one-period or direct Granger noncausality; causality may arise indirectly at longer horizons, via one or more auxiliary variables in the system.

3. Testing for direct and indirect Granger noncausality in VARs

Causality between exports and economic output is explored using various model frameworks, based upon an underlying levels VAR(p):

$$\Phi_p(L)z_t = e_t, \quad t=p+1, \dots, T, \quad (1)$$

where z_t is a k-dimensional vector multiple time series, $z_t = (z_{1t}, z_{2t}, \dots, z_{kt})^T$, two components of which are a measure of export activity and economic output (e.g., real exports and real gross domestic product); the other components in z are the auxiliary variables in the information set,

believed necessary to reasonably describe the relationships in the system. The lag polynomial $\Phi_p(L)$ is of order p , with $\Phi_p(L) = I - \Phi_1 L - \dots - \Phi_p L^p$, $L^\ell z_t = z_{t-\ell}$, Φ_ℓ is a $k \times k$ parameter matrix with (i,j) th element $\phi_{ij,\ell}$ that provides the (partial) impact of $z_{j,t-\ell}$ on z_{it} , $i,j=1,\dots,k$, $\ell=1,\dots,p$; and the error vector e_t is such that $E(e_t) = 0$, $E(e_t e_{t-s}) = 0$, if $s \neq t$, $= \Sigma$, if $s=t$, with $\det(\Sigma) \neq 0$. The system (1) is initialized at $t=1, \dots, p$ with the initial values being any random vectors, including constants.

Typically, $z_t = y_t - \mu_t$, where μ_t contains assumed deterministic terms. Given the characteristics of our data, we model μ_t as: $\mu_t = \mu + \delta t$, where t is a linear time trend. System (1) is then the usual VAR in levels:

$$y_t = \mu^* + \delta^* t + \sum_{\ell=1}^p \Phi_\ell y_{t-\ell} + e_t \quad (2)$$

where $\mu^* = (-\Pi\mu + \Pi^*\delta)$, $\delta^* = -\Pi\delta$, $\Pi^* = \sum_{\ell=1}^p \ell \Phi_\ell$, and Π is the potentially reduced rank matrix:

$$\Pi = - \left(I_k - \sum_{\ell=1}^p \Phi_\ell \right). \text{ We assume that all the roots of } \left| I_k - \sum_{\ell=1}^p \Phi_\ell x^\ell \right| = 0 \text{ lie outside the complex}$$

unit circle, except for possibly some unit roots; with integrated variables, the rank of Π equals the dimension of the cointegrating space. We can also write (1) and (2), with $\Gamma_\ell = - \sum_{\partial=\ell+1}^p \Phi_\partial$, as a

VECM($p-1$):

$$\Delta y_t = \Pi^* \delta + \Pi (y_{t-1} - \mu - \delta t) + \sum_{\ell=1}^{p-1} \Gamma_\ell \Delta y_{t-\ell} + e_t \quad (3)$$

which, when $\text{rank}(\Pi) = r$ leading to the decomposition $\Pi = \alpha \beta^T$, can be written as:

$$\Delta y_t = \Pi^* \delta + \alpha (\beta^T y_{t-1} - \mu_0 - \delta_0 t) + \sum_{\ell=1}^{p-1} \Gamma_\ell \Delta y_{t-\ell} + e_t \quad (4)$$

where $\mu_0 = \beta^T \mu$ and $\delta_0 = \beta^T \delta$. In this paper we work with the VAR in levels of the variables, given by (2), rather than the VECM, to avoid issues associated with pretests for integration and cointegration; e.g., Clarke and Mirza (2005).

3.1 Horizon-1 autoregression

Writing (2) at time $(t+1)$, rather than at time t , highlights that it is an autoregression at horizon 1 (Dufour and Renault, 1998; Dufour et al., 2005), which we denote as a horizon-1 autoregression:

$$y_{t+1} = \mu^* + \delta^*(t+1) + \sum_{\ell=1}^p \Phi_{\ell} y_{t+1-\ell} + e_{t+1} \quad (5)$$

Direct, or one-period ahead or horizon-1, Granger-causality from y_j to y_i occurs when $\phi_{ij,\ell} \neq 0$ for at least one $\ell = 1, \dots, p$. This leads to the usual null hypothesis, for (direct) horizon-1 Granger-noncausality, which we denote by $y_j \not\rightarrow_1 y_i$, of $H_0^1 : \phi_{ij,\ell} = 0 \forall \ell = 1, \dots, p$, commonly tested with a Wald statistic, say W^1 .

3.2 Horizon-2 autoregression

Following Dufour et al. (2005), we now write (2) at time $(t+2)$:

$$y_{t+2} = \mu^* + \delta^*(t+2) + \sum_{\ell=1}^p \Phi_{\ell} y_{t+2-\ell} + e_{t+2}$$

which, on substitution of (5), gives a horizon-2 autoregression:

$$y_{t+2} = \mu^* (I + \Phi_1) + \delta^* (\Phi_1 + 2) + \delta^* t(I + \Phi_1) + \sum_{\ell=1}^p (\Phi_1 \Phi_{\ell} + \Phi_{\ell+1}) y_{t+1-\ell} + (e_{t+2} + \Phi_1 e_{t+1}) \quad (6)$$

so that y_j does not Granger-cause y_i at horizon 2 when $\left(\sum_{\omega=1}^k \phi_{i\omega,1} \phi_{\omega j, \ell} \right) + \phi_{ij, \ell+1} = 0 \forall \ell = 1, \dots, p$,

which we denote by $y_j \not\rightarrow_2 y_i$. The second terms of this expression measure the *direct* impact of y_j on y_i , while the first terms, in parentheses, indicate how y_j can *directly* and *indirectly* impact y_i via each variable in turn. When $y_j \not\rightarrow_1 y_i$, $\phi_{ij,\ell} = 0 \forall \ell$, Granger-causality from y_j to y_i will arise

at horizon 2 (i.e., $y_j \rightarrow_2 y_i$) when $\left(\sum_{\substack{\omega=1 \\ \omega \neq i,j}}^k \phi_{i\omega,1} \phi_{\omega j, \ell} \right) \neq 0$ for at least one $\ell = 1, \dots, p$, which highlights

the indirect nature in which causality can arise via auxiliary variables in the system, even when there is (direct) horizon-1 noncausality. In principle, tests could be constructed to examine

$$H_0^2 : \left(\sum_{\omega=1}^k \phi_{i\omega,1} \phi_{\omega j, \ell} \right) + \phi_{ij, \ell+1} = 0, \forall \ell = 1, \dots, p \text{ and/or } H_0^2 | H_0^1 : \left(\sum_{\substack{\omega=1 \\ \omega \neq i,j}}^k \phi_{i\omega,1} \phi_{\omega j, \ell} \right) = 0, \forall \ell = 1, \dots, p ;$$

e.g., see Giles (2002) for such strategies for a trivariate model. Complications may arise,

however, as we are testing zero restrictions on multilinear functions of the coefficients, which may lead to rank issues and nonstandard asymptotic limiting distributions; see Dufour and Renault (1998). We note that a moving average error of order one has been introduced, with the substitutions, in the horizon-2 autoregression; this will need to be accounted for in estimation and inference.

To avoid difficulties associated with the restrictions in (6), Dufour et al. (2005) suggest consideration of an unrestricted version:

$$y_{t+2} = \bar{\mu} + \bar{\delta}t + \sum_{\ell=1}^p \bar{\Phi}_{\ell} y_{t+1-\ell} + e_{t+2} + \Phi_1 e_{t+1} \quad (7)$$

where $\bar{\Phi}_{\ell}$ is a $k \times k$ parameter matrix with $(i,j)^{\text{th}}$ element $\bar{\phi}_{ij,\ell}$ that provides the (partial) impact of $y_{j,t+1-\ell}$ on $y_{i,t+2}$. A Wald test, using a test statistic denoted by W^2 , can then be undertaken to test whether $y_j \rightarrow y_i$ by examining sample compatibility with $H_0^2: \bar{\phi}_{ij,\ell} = 0 \forall \ell = 1, \dots, p$.

Efficiency and power losses are probable consequences of working with (7), rather than (6), as some information has been ignored.

3.3 Horizon-h autoregression

It now follows that a horizon-h autoregression is obtained by writing (2) at time $(t+h)$:

$$y_{t+h} = \mu^* + \delta^*(t+h) + \sum_{\ell=1}^p \Phi_{\ell} y_{t+h-\ell} + e_{t+h}$$

which, with appropriate substitutions, as shown in Dufour and Renault (1998), is:

$$y_{t+h} = \sum_{\kappa=0}^{h-1} \Phi_1^{(\kappa)} (\mu^* + \delta^*(t+h-\kappa)) + \sum_{\ell=1}^p \Phi_{\ell}^{(h)} y_{t+1-\ell} + \sum_{\kappa=0}^{h-1} \Psi_{\kappa} e_{t+h-\kappa} \quad (8)$$

where $\Psi_0 = I_k$, $0 \leq h < T$ and:

$$\Phi_{\ell}^{(h+1)} = \Phi_{\ell+h} + \sum_{\kappa=1}^h \Phi_{h-\kappa+1} \Phi_{\ell}^{(\kappa)} = \Phi_{\ell+1}^{(h)} + \Phi_1^{(h)} \Phi_{\ell}, \quad \Phi_1^{(0)} = I_k, \quad \Phi_{\ell}^{(1)} = \Phi_{\ell}, \quad \Psi_h = \Phi_1^{(h)}.$$

Consistent with the horizon-2 autoregression, the coefficients in (8) are multilinear functions of the original parameter matrices and we have a moving average error of order $(h-1)$; Dufour et al. (2005) suggest, given the difficulties associated with testing from this representation, we examine the unrestricted model:

$$y_{t+h} = \bar{\mu}_h + \bar{\delta}_h t + \sum_{\ell=1}^p \bar{\Phi}_{h,\ell} y_{t+1-\ell} + \sum_{\kappa=0}^{h-1} \Psi_{\kappa} e_{t+h-\kappa} \quad (9)$$

where $\bar{\Phi}_{h,\ell}$ is a $k \times k$ parameter matrix with $(i,j)^{\text{th}}$ element $\bar{\phi}_{ij,h,\ell}$ that provides the (partial) impact of $y_{j,t+1-\ell}$ on $y_{i,t+h}$. We then test whether y_j is Granger noncausal for y_i at horizon h , which we denote by $y_j \not\rightarrow_h y_i$, by examining sample compatibility with $H_0^h : \bar{\phi}_{ij,h,\ell} = 0 \forall \ell = 1, \dots, p$, using, for example, an appropriately constructed Wald statistic, say W^h . We term (9) a horizon- h autoregression.

To obtain sample values for W^h ($h > 1$), we need to allow for the MA($h-1$) error process and that y may contain one or more integrated series that may be cointegrated, which may affect the limiting null distribution of W^h ; see Toda and Phillips (1993, 1994). Dufour et al. (2005) suggest that continuing to use the seemingly unrelated least squares estimator (SURE) with a heteroskedastic-autocorrelation consistent (HAC) estimator of its variance-covariance matrix is likely the most user friendly approach to accommodate the moving average terms; we follow their suggestion here. We use two approaches to allow for the impact that (co-)integration might have on moving W^h away from being asymptotically $\chi^2(p)$ under the null of horizon- h GNC:

- (i) A variable-addition or augmentation method, proposed by Toda and Yamamoto (1995) and Dolado and Lütkepohl (1996), whereby we augment (9) with one or more additional lags of y , depending on the highest order of integration in the system. The statistic W^h is formed, then, from restrictions on all of the coefficient matrices, except for those associated with the additional lag(s). We term this the TYDL- h method associated with our horizon- h autoregression. Dufour et al. (2005) show, following Toda and Yamamoto (1995) and Dolado and Lütkepohl (1996), who build on, for example, Sims et al. (1990) and Choi (1993), this will result in W^h being a $\chi^2(p)$ asymptotic variate under H_0^h . Assuming y_t is at most $I(1)$, a reasonable proposition for our study from other empirical research, and allowing for the MA error process via use of a HAC covariance estimator, implies we estimate:

$$y_{t+h} = \bar{\mu}_h + \bar{\delta}_h t + \sum_{\ell=1}^p \bar{\Phi}_{h,\ell} y_{t+1-\ell} + \bar{\Phi}_{h,a} y_{t-a} + u_{t+h} \quad (10)$$

where, typically, $a=p+1$, although $a=-(h-1)$ also works and might be preferred when data is limited. Having formed a sample value for W^h , we compare its $\chi^2(p)$ p-value with a (nominal) α significance level.

- (ii) A subsampling strategy, proposed by Choi (2005) that we denote as SUB- h , based on blocks of consecutive observations of length b , which enables us to approximate the quantiles of the finite sample null distribution of W^h irrespective of whether y_t is integrated and cointegrated. Using SUB- h may lead to more accurate inference than TYDL- h , as conclusions

from the latter are based on p-values formed from the limiting null distribution, which may be a poor approximation to the finite sample null distribution in sample sizes commonly used in practice; e.g., Stock (1997). We consider Choi's centered subsampling scheme. The steps are:

Step 1: Estimate, using SUR with a HAC estimator for the covariance matrix,

$$y_{t+h} = \bar{\mu}_h + \bar{\delta}_h t + \sum_{\ell=1}^p \bar{\Phi}_{h,\ell} y_{t+1-\ell} + u_{t+h} \quad (11)$$

over the full-sample of $n_h=(T-p-h+1)$ available observations. Let: $\bar{\Gamma}_h$ be a $k(kp+2)$ -dimensional vector that contains the parameters in (11) to be estimated; $\hat{\Gamma}_h$ be the associated SUR estimator with HAC covariance matrix \hat{V}_h . Write $H_0^h : \bar{\Phi}_{ij,h,\ell} = 0 \quad \forall \ell = 1, \dots, p$, as $H_0^h : R_h \bar{\Gamma}_h = 0$, where R_h , a $p \times k(kp+2)$ nonstochastic, full rank, selection matrix, provides the appropriate restrictions under test. Form the full-sample Wald statistic to examine H_0^h :

$$W^h = n_h \hat{\Gamma}_h^T R_h^T \left[R_h \hat{V}_h R_h^T \right]^{-1} R_h \hat{\Gamma}_h \quad (12)$$

Step 2: Estimate, using SUR with a HAC estimator for the covariance matrix:

$$y_{t+h} = \bar{\mu}_h + \bar{\delta}_h t + \sum_{\ell=1}^p \bar{\Phi}_{h,\ell} y_{t+1-\ell} + u_{t+h} \quad (13)$$

for the $n_{h,b}=(T-p-h-b+2)$ possible subsamples of consecutive observations of block size b .

Let $\hat{\Gamma}_{h,s}$ be the SUR estimator of $\hat{\Gamma}_h$ with HAC covariance matrix $\hat{V}_{h,s}$ for the s^{th} subsample;

$s=1, \dots, n_{h,b}$. For each estimated subsample model, form the centered Wald statistic, W_s^h :

$$W_s^h = n_h \left(\hat{\Gamma}_{h,s} - \hat{\Gamma}_h \right)^T R_h^T \left[R_h \hat{V}_{h,s} R_h^T \right]^{-1} R_h \left(\hat{\Gamma}_{h,s} - \hat{\Gamma}_h \right) \quad (14)$$

where the "centering" is around the full-sample value $R_h \hat{\Gamma}_h$ rather than the usual zero vector.

Step 3: Form the subsampling empirical p-value for testing H_0^h as:

$$p_b = \frac{1}{n_{h,b}} \sum_{s=1}^{n_{h,b}} I \left[W_s^h \geq W^h \right]$$

which we compare with 0.10, our chosen significance level for the test⁴.

⁴ Although Choi's proof of the validity of his proposed subsampling method assumes iid errors, which could be relaxed to a stationary, martingale difference error process, it is likely that the approach is still valid under our assumptions, given our adoption of a HAC variance-covariance estimator for the coefficient vector when forming relevant Wald statistics.

Application of these steps requires a block size, b , which determines the size of the subsamples. Choi recommends a calibration rule obtained from his simulation experiments, which for our models does not lead to enough observations for estimation. Accordingly, we adopt a block size of 25 observations.

4. Data and some further modeling issues

Annual data are from the World Bank's *World Development Indicators* (WDI) for 1960 through 2003⁵. Variables in our study are: exports (*exp*), gross domestic product (*gdp*), terms of trade adjustment (*tot*) and gross capital formation (*gcf*); when relevant, each variable is in 1995 U.S. million dollars; the web site <http://www.worldbank.org/data/aboutdata/working-meth.html> details the World Bank's method for converting series into constant U.S. dollars. Definitions, as provided by the WDI, are given in Table 2.

Table 2
Variable definitions

Variable	Definition
<i>exp</i>	Exports of goods and services. This represents the value of all goods and other market services provided to or received from the world. Included is the value of merchandise, freight, insurance, travel, and other nonfactor services. Factor and property income (formerly called factor services), such as investment income, interest, and labor income, is excluded.
<i>gdp</i>	Gross domestic product. This is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.
<i>tot</i>	Terms of trade adjustment. This equals capacity to import less exports of goods and services in constant prices. Capacity to import equals the current price value of exports of goods and nonfactor services deflated by the import price index.
<i>gcf</i>	Gross capital formation. This consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and "work in progress." Net acquisitions of valuables are also considered capital formation.

⁵ The data for Sri Lanka excludes the areas controlled by the LTTE.

A terms of trade variable and a capital formation variable are frequently adopted as auxiliary information in export-led growth studies for Bangladesh and Sri Lanka; e.g., Hutchison and Singh (1992), Sharma and Dhakal (1994), Arnade and Vasavada (1995), Islam (1998) and Love and Chandra (2004). Giles and Williams (2000b) provide details of the wide range of ancillary series included in over 150 export-led growth studies; although other variables to ours have been considered, our chosen ancillary variables are common choices. Increases in capital formation are perhaps one of the most direct means of improving economic welfare, and, likely, output; capital formation may also lead to higher exports with, for example, better access to equipment, plants, and infrastructure to transport goods.

The impact of terms of trade on output is well recognized; e.g., an improvement in the terms of trade, similar to a technological advance, makes it feasible to increase net output for a fixed amount of domestic inputs (see, e.g., Diewert and Morrison (1986)). Volatility in terms of trade is usually destabilizing, as sudden movements can lead to changes in trade balances and current accounts, with possible sectoral output consequences. We expect a negative impact on output from volatile trade imbalances and deteriorating terms of trade. Falling and/or fluctuating terms of trade may also dampen export-oriented production, as lower profitability is a likely outcome, unless there are also offsetting exchange-rate movements. Despite the fact that causal outcomes are likely sensitive to our selection of *tot* and *gcf*, our consideration of these ancillary variables enables the importance of the horizon in determining causal relationships to be illustrated.

We provide some summary descriptive statistics for the data in Table 3. Aside from the striking feature of the high proportion of exports share of gdp in Sri Lanka compared to Bangladesh, we note that this statistic has grown steadily in Bangladesh over the last decade or so, compared to the 1960s to 1980s, while it has remained more stable in Sri Lanka. Exports have been vital to Sri Lanka's economy, while they are becoming more so for Bangladesh.

Table 3
Some descriptive statistics

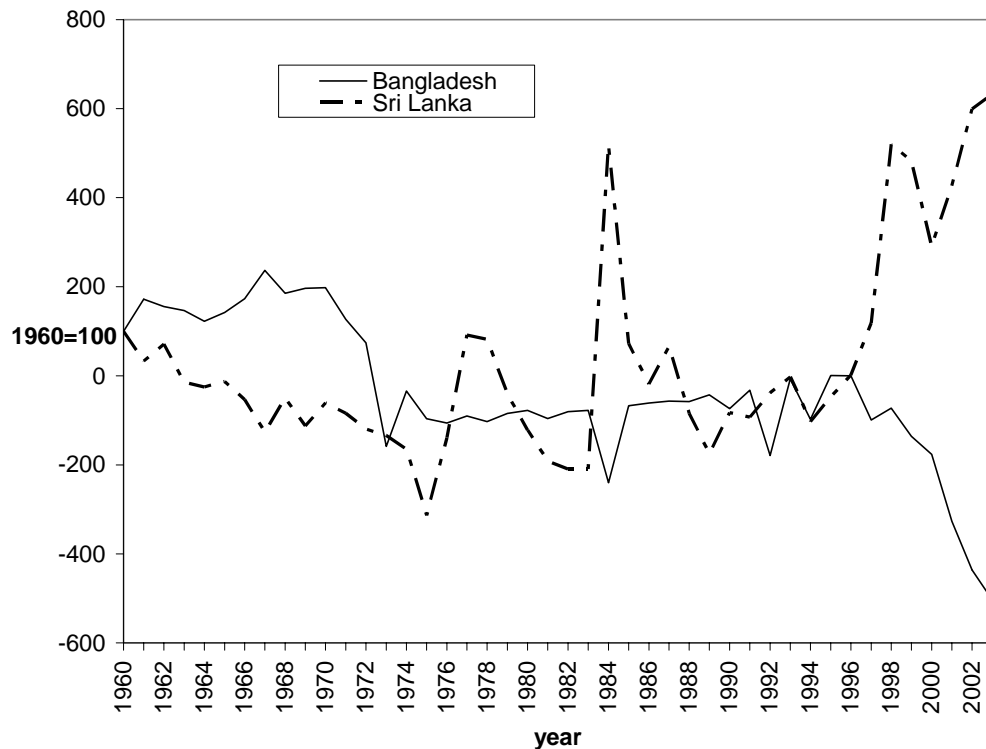
Period	<i>exp</i> as % of <i>gdp</i> (average p.a.)	Average % growth p.a.		
		<i>exp</i>	<i>gdp</i>	<i>gcf</i>
Bangladesh				
1960-1969	4.84%	2.65%	3.89%	15.39%
1970-1979	4.93%	7.96%	2.20%	5.00%
1980-1989	5.99%	5.01%	3.28%	9.97%
1990-1999	10.00%	12.65%	4.80%	8.38%
2000-2003	14.21%	6.65%	5.24%	6.91%
1960-1979	4.88%	5.45%	3.00%	9.92%
1980-2003	9.03%	8.46%	4.24%	8.80%
1960-2003	7.15%	7.13%	3.69%	9.29%
Sri Lanka				
1960-1969	46.37%	1.32%	4.67%	7.70%
1970-1979	31.74%	1.92%	4.23%	14.90%
1980-1989	28.51%	4.90%	4.15%	2.15%
1990-1999	34.58%	6.99%	5.26%	6.50%
2000-2003	39.19%	5.95%	3.48%	3.72%
1960-1979	39.05%	1.63%	4.43%	11.49%
1980-2003	32.82%	5.94%	4.50%	4.22%
1960-2003	35.65%	4.04%	4.47%	7.43%

Notwithstanding such features, the average per annum growth of Bangladeshi exports has outstripped the average annual growth in *gdp* since the 1970s, with double digit annual average growth for the 1990s. This has occurred in an environment of annual *gdp* growth averages that would be the envy of many developed countries; such rates of growth are recognized as being necessary if Bangladesh is to resolve many of its economic and social problems. Capital formation, perhaps the most readily apparent determinant of future living standards, has also shown impressive rates of growth, especially over the 1960s and 1980s.

Sri Lanka's average annual growth in exports has been between 5% and 7% since the 1980s, in an environment of expanding *gdp*, with annual rates usually above 4% on average over the period; the slow down in 2001 has dragged down the average over 2000-2003, but the raw figures indicate the return to 4-5% annual growth in *gdp* since 2001. The average growth in capital formation, in the first two decades of our sample, was impressive, but has been less so since the 1980s. Despite this slowdown, Sri Lanka has been expanding its capital base, along with its steady growth in the economy and exports.

We graph the terms of trade adjustment, converted to an index with 1960=100, for both countries in Figure 1. As a proxy for trade shocks, we see that Sri Lanka has faced higher volatility than has Bangladesh. Sharp movements in terms of trade can be destabilizing for an economy due to the likely impact on trade balances and current accounts, in addition to possible sectoral effects on output.

Figure 1
Terms of trade adjustment index



Bangladesh has faced a negative trade balance since independence in 1971, deteriorating substantially since the mid 1990s. Importation of crude oil and petroleum products, along with grain and other food needs, dominates the cost of imports, outweighing export earnings from the key exports: jute and ready-made garments. Rising import prices, alongside a reasonably static export price index, have substantially contributed to the decline in the terms of trade, although this has not deterred exporting.

Sri Lanka has confronted a serious balance of trade deficit since the late 1950s, with increasing demand for imports, due to population growth and rising expectations, alongside a falling ability to pay with the relative price declines in tea, rubber and coconut. This shortfall in foreign exchange has been problematic for economic advancement, and has led to increased foreign support and borrowing since the late 1970s, further deteriorating the country's ability to import needed goods. There have been occasional exceptions to this general pattern; e.g., between 1976 and 1977, and in 1984 with an increase in the price of tea. Since the mid 1990s, with growing global demand for Sri Lankan products (e.g., textiles) accompanied by export price increases outstripping import price increases, the terms of trade have steadily improved, aside

from a blip in 1999, which reflects a lagged effect of a depressed global market with lower commodity prices.

Prior to undertaking the noncausality tests, we must specify the order for our VARs, given by system (2), which is important in order to avoid spurious findings of causality or noncausality. Common methods include using information criteria (e.g., Akaike's (1973) information criterion (AIC), Schwarz's (1978) Bayesian criterion (SC), Akaike's (1969) final prediction error criterion (FPE) and Hannan and Quinn's (1979) information criterion (HQ)) and a likelihood ratio (LR) general to specific sequential testing strategy. Although the AIC and FPE criteria are inconsistent estimators of the lag order, having a positive probability of overestimating the order, research (e.g., Cheung and Lai, 1993; Gonzalo and Pitarakis, 1998) suggests this may be preferable to being parsimonious, as may arise with use of the SC and HQ. Others (e.g., Lütkepohl (1985)) propose that the SC and HQ perform best. Which should we use? We follow the approach advocated by Hatemi-J (2003) of taking the average of the lags from these criteria, which leads to a VAR(5) for both Bangladesh and Sri Lanka.

Having determined lag orders, it remains to estimate the systems at each horizon, undertake the relevant hypothesis tests and determine the associated p-values. There are twelve hypotheses to examine for a given h , one for each possible pairwise noncausal relation. Using the results of Proposition 4.5 in Dufour and Renault (1998), the highest horizon we need to examine is $h=11$; that is, as we have two auxiliary variables in each case, with a lag order of five, it is sufficient to have noncausality up to horizon 11 ($=2 \times 5 + 1$) for there to be noncausality at all horizons. Accordingly, we consider our twelve hypotheses for $h=1, \dots, 11$. We use a nominal significance level of 10% when deciding on whether to support or reject a noncausality null hypothesis.

5. Empirical results

Rather than presenting a table of difficult to assimilate p-values, we provide our results as eleven causal maps – one for each horizon. A causal map is an example of a “directed graph”, with an arrow leading from one variable to another; they indicate the presence or absence of causality between pairs of variables at that horizon. For instance, the causal map for Bangladesh using the SUB- h approach when $h=1$, provided in Figure 2, indicates unidirectional causality from *gcf* to *exp* and from *gcf* to *gdp*, and bidirectional causality between *tot* and *gcf*, but no causality between either *exp* and *gdp* or *exp* and *tot*.

5.1 Bangladesh

We provide causal maps in Figures 2 and 3, and the lowest horizon at which a pairwise causal relation arises in Table 4. Several features are evident:

1. At least at short horizons, the SUB-h method, based on the subsampling procedure suggested by Choi (1995), results in “less” pairwise causal outcomes than does the augmented lag TYDL-h approach. In particular, the latter suggests one-period export-led growth, whereas there is no evidence of causality between exports and *gdp* using SUB-h. This feature likely arises from the known tendency of the TYDL method to over-reject the noncausal null (e.g., see the simulations presented in Yamada and Toda (1998) and Clarke and Mirza (2005)), as well as, perhaps, the propensity of the SUB-h to sometimes under-reject in small samples (see Choi (1995)).
2. Irrespective of these nuances with approach, we detect significant bidirectional causality between *exp* and *gdp* at a longer horizon than one-period via the indirect causal relations of the other variables in the system. With the SUB-h approach, we observe $gdp \xrightarrow{2} exp$ and $exp \leftrightarrow_5 gdp$, while TYDL-h suggests $exp \xrightarrow{1} gdp$ and $gdp \leftrightarrow_3 exp$. These results highlight that it is not reasonable to assume that the one-period causal patterns indicate the full extent of the causal relationships between *exp* and *gdp* in Bangladesh. Indeed, there are linkages between *exp* and *gdp* that take between three and five periods to appear.
3. We find significant causal links between each possible pair of variables; that is, there are no noncausal links in this system. The longest horizon in which a causal link arises is seven years for *tot* and *gdp* with SUB-h, and six years for *gcf* to be causal for *exp* with TYDL-h.
4. The direct and indirect causality outcomes stress the relevance of investment and terms of trade in bringing about links between *exp* and *gdp* for Bangladesh, and indicate the dynamic relations between the four variables in working together in the development of Bangladesh’s economy. That we observe this feature is unexpected, given our discussion, albeit brief, on Bangladesh’s background in sub-section 2.1.

5.2 Sri Lanka

We present causal maps for Sri Lanka in Figures 4 and 5, along with the shortest horizon at which a causal link arises in Table 4. From these, we observe:

1. As for the Bangladeshi case, we detect more “significant” causal patterns from the TYDL-h route than from the SUB-h method.

2. Irrespective of approach, there is lack of one-period causality between *exp* and *gdp*, which accords with the recent findings of Love and Chandra (2004). However, the benefit of examining for causality at higher horizons is clear – bidirectional causality between *exp* and *gdp* arises at higher horizons via the indirect causal relations present in the system at lower horizons. At horizon 6, we detect bidirectional causality between *exp* and *gdp* with SUB-h, whereas TYDL-h indicates such a feature arising at horizon 3. The effects of *tot* and *gcf* on *exp* and *gdp*, and on each other, bring about the feedback between *gdp* and *exp* after sufficient time. These results accord with our expectation, given the background provided for Sri Lanka in sub-section 2.2.
3. All the variables in our system are ultimately pairwise causal; i.e., there is no evidence of noncausality. The longest horizon is six years using SUB-h, while it is five years using TYDL-h.

Table 4
Lowest horizon at which causality occurs

Causal Relation	Bangladesh		Sri Lanka	
	SUB-h	TYDL-h	SUB-h	TYDL-h
<i>exp</i> → <i>gdp</i>	5	1	6	3
<i>exp</i> → <i>gcf</i>	5	2	6	4
<i>exp</i> → <i>tot</i>	5	1	6	1
<i>tot</i> → <i>gdp</i>	7	1	1	1
<i>tot</i> → <i>gcf</i>	1	1	1	1
<i>tot</i> → <i>exp</i>	7	2	1	1
<i>gcf</i> → <i>gdp</i>	1	2	1	2
<i>gcf</i> → <i>tot</i>	1	1	1	5
<i>gcf</i> → <i>exp</i>	1	6	1	1
<i>gdp</i> → <i>exp</i>	2	3	6	3
<i>gdp</i> → <i>gcf</i>	4	2	1	1
<i>gdp</i> → <i>tot</i>	7	1	1	3

6. Concluding remarks

The two South Asian developing countries, Bangladesh and Sri Lanka, although dissimilar in many ways, have both promoted exporting as a way to enhance economic growth, along side a struggle to reform domestically, remove or simplify import restrictions, ensure political stability, encourage investment and alleviate poverty, which should also improve output and lead, in time, to further exporting. Both countries have experienced increases in exports, national output and capital formation, along with some volatile terms of trade, which, in conjunction with each country's developmental plans, would suggest that dynamic links should exist between exports,

national output, capital formation and terms of trade. Often these expected links are not empirically evident. We show that the commonly used Granger-causality tool, once we allow for causality at longer horizons than one-period ahead, via indirect causal links from ancillary variables, reveals the expected causal links. It takes time – the horizon matters. Irrespective of country or adopted method, we provide evidence of dynamic links between all variables in the system. Exporting, either directly or indirectly via the ancillary variables, is causally linked with economic output. Our results underscore the importance of moving beyond one-period ahead Granger-causality when attempting to determine causal relationships in a system of related variables.

Interestingly, the importance of capital formation and terms of trade in bringing about the observed causal feedback between exports and output is a key outcome. Consequently, despite our finding of causal links between exports and output, our results should not be interpreted as indicating definitive support for an “export-led growth” strategy; i.e., as support for the stance that exporting is an essential determinant of economic growth. Rather, they would appear to suggest the notion that exporting, investment, trade shocks and output are intricately linked with each other, implying perhaps, as advocated by, for example, Rodrik (1992, 2001) and Lall (1996, 2004), that export promotion is only one arm of economic development – investment, political and macroeconomic stability, internal reforms and other domestic policies are equally crucial.

Many other factors, than just those we examined, are commonly proposed as being associated with development: e.g., the acquisition of skills and knowledge through education, training, experience and research; a stable and well-developed financial system; stable and low inflation; balanced fiscal policy; the level of inequality and poverty; the form of a country’s political system, including the degree of government interference in the economy and the level of corruption. Future research is needed to understand the causal impact of these factors in developing countries such as Bangladesh and Sri Lanka.

Figure 4
Granger causal maps for Sri Lanka using SUB-h

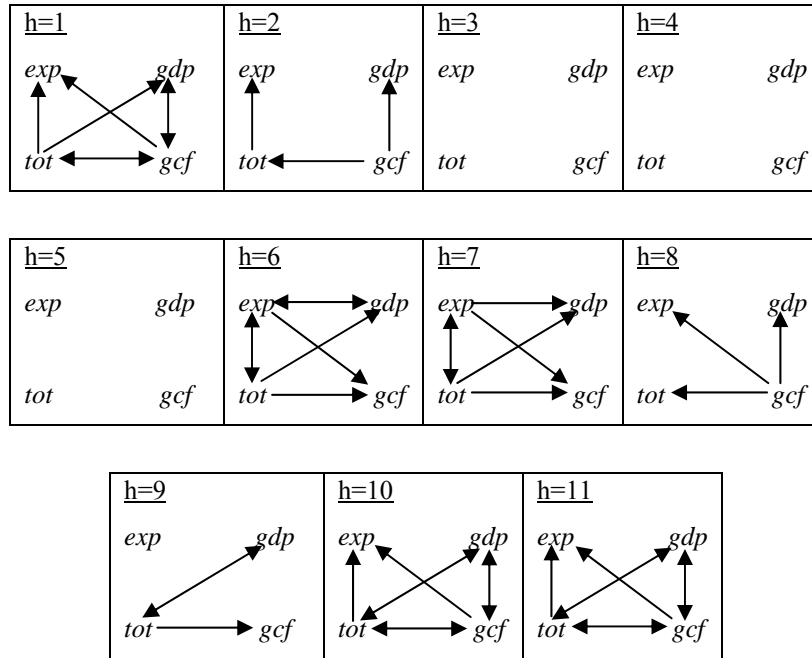
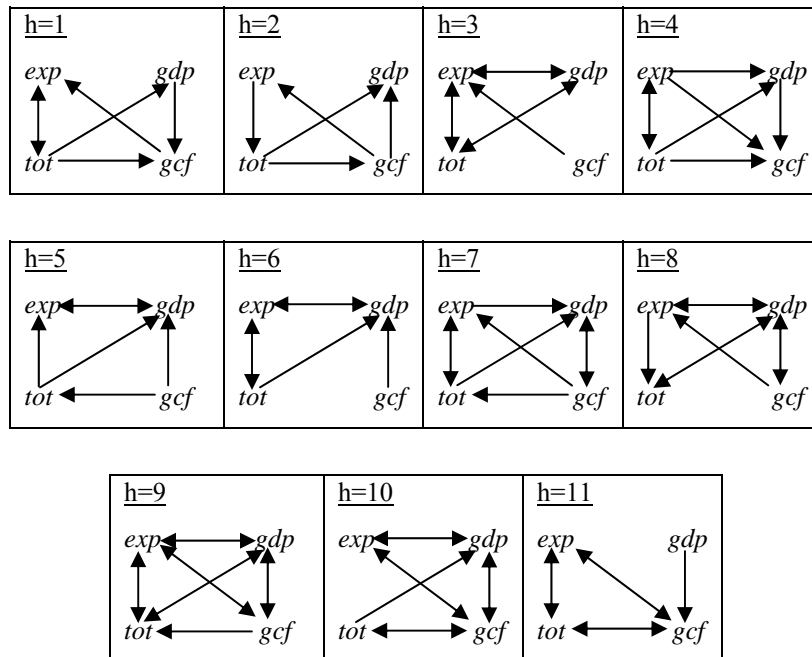


Figure 5
Granger causal maps for Sri Lanka using TYDL-h



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