Empirical Economics (1996) 21:77–110

The Engine of Growth or its Handmaiden?
A Time-Series Assessment of Export-Led Growth

RAYMOND G. RIEZMAN AND CHARLES H. WHITEMAN[1]

Department of Economics, University of Iowa, Iowa City IA 52242, USA

PETER M. SUMMERS

Department of Economics and Centre for International Economic Studies, University of Adelaide, Adelaide SA 5005, Australia

Abstract: This paper presents an analysis of time-series data for the countries in the Summers-Heston (1991) data set, in an attempt to ascertain the evidence for or against the export-led growth hypothesis. We find that standard methods of detecting export-led growth using Granger-causality tests may give misleading results if imports are not included in the system being analyzed. For this reason, our main statistical tool is the measure of conditional linear feedback developed by Geweke (1984), which allows us to examine the relationship between export growth and income growth while controlling for the growth of imports. These measures have two additional features which make them attractive for our work. First, they go beyond mere *detection* of evidence for export-led growth, to provide a measurement of its *strength.* Second, they enable us to determine the temporal pattern of the response of income to exports. In some cases export-led growth is a long-run phenomenon, in the sense that export promotion strategies adopted today have their strongest effect after eight to 16 years. In other cases the opposite is true; exports have their greatest influence in the short run (less than four years). We find modest support for the export-led growth hypothesis, if "support" is taken to mean a unidirectional causal ordering. Conditional on import growth, we find a causal ordering from export growth to income growth in 30 of the 126 countries analyzed; 25 have the reverse ordering. Using a weaker notion of "support" – stronger conditional feedback from exports to income than vice versa, 65 of the 126 countries support the export-led growth hypothesis, although the difference in strength is small. Finally, we find that for the "Asian Tiger" countries of the Pacific Rim, the relationship between export growth and output growth becomes clearer when conditioned on human capital and investment growth as well as import growth.

Key Words: Export-led growth, time series, causality

JEL Classification System-Numbers: F14, F43, C32

[1] We are grateful to J. David Richardson, Narayana Kocherlakota, Tin Nguyen, two anonymous referees, and seminar participants at the 1992 Midwest International Economics meetings, the University of Adelaide, and the 1994 conference of the Economics Society of Australia, for helpful comments and discussions. The analysis of the Penn-World Table (Mark 5.5) was greatly simplified by the spreadsheet macros and templates developed by Dr. Sailesh K. Tanna of the Coventry Business School. Riezman and Whiteman acknowledge support from the National Science Foundation, under grants SES 90-23056 and SES 89-22419, respectively. Any remaining errors are our own.

0377-7332/96/1/77-110 $2.50

1 Introduction

One of the most enduring questions in economics involves how a nation could accelerate the pace of its economic development. One of the most enduring answers to this question is to promote exports – either because doing so directly influences development via encouraging production of goods for export, or because export promotion permits accumulation of foreign exchange which permits importation of high-quality goods and services, which can in turn be used to expand the nation's production possibilities. In either case, growth is said to be *export-led*; the latter case is the so-called "two-gap" hypothesis (McKinnon, 1964; Findlay, 1973).

The early work on export-led growth consisted of static cross-country comparisons (Michaely, 1977; Balassa, 1978; Tyler, 1981; Kormendi and Meguire, 1985). These studies generally concluded that there is strong evidence in favour of export-led growth because export growth and income growth are highly correlated. However, Kravis pointed out in 1970 that the question is an essentially dynamic one: as he put it, are exports the handmaiden or the engine of growth? To make this determination one needs to look at time series to see whether or not exports are driving income. This approach has been taken in a number of papers (Jung and Marshall, 1985; Chow, 1987; Serletis, 1992; Kunst and Marin, 1989; Marin, 1992; Afxentiou and Serletis, 1991), designed to assess whether or not individual countries exhibit statistically significant evidence of export-led growth using Granger causality tests.

We adopt this dynamic approach, but make a number of important modifications. First, we use data from a single source designed to provide a consistent set of comparable cross-country statistics on output – the purchasing power index data of Summers and Heston (1991). This data set avoids the standard difficulty that output valued at official exchange rates may not provide an accurate picture of a nation's stage of economic development. The intertemporal effect of this phenomenon is especially important when one is interested in the pattern of economic development. For example, as a country develops, its traded (i.e., exported) goods sector may grow relative to other sectors. Thus just as output has grown, the official-exchange-rate valuation of output will more accurately measure actual output precisely because exports constitute a larger fraction of output. This will make it appear to be the case that exports lead output regardless of the underlying source of output growth. Use of the purchasing power measure attenuates this confounding measurement error effect, since its valuation of output relies less heavily on a country's traded goods. This paper uses data from Mark 5.5 of the Penn-World Table (Summers and Heston, 1991), which covers the years 1950–1990.[2] Our measure of income growth is total *real*

[2] Although the Summers-Heston (1991) paper includes data only through 1988 (Mark 5), an updated version (Mark 5.5) includes data through 1990. This version is available via anonymous ftp

gross domestic product in *current* international dollars, which is computed by multiplying the CGDP series for each country by its population. Exports and imports are also expressed in current international dollars, and are derived from the Penn-World Table.[3]

Second, this paper strives to provide a consistent set of *measurements* of the importance of exports in leading economic growth. We employ several procedures which, while not new, have not previously been applied to this problem. These measures enable us to go beyond mere *detection* of evidence for export-led growth to the measurement of its strength.

The third modification is that we take account of imports explicitly. Other studies typically focus on the bivariate relationship between income and exports.[4] But as noted above, theory suggests that imports may play a central role in explaining export-led growth. Indeed, we find that omitting imports from the analysis may either mask or overstate the effect of exports on income.

Fourth, for a subset of countries, we also investigate whether other often-omitted variables influence the relationship between income and exports. In particular, we find that conditioning on measures of physical and human capital generally sharpens inferences regarding the relationship between export growth and output growth.

Finally, we are able to determine the temporal pattern of the response of income to exports. In some cases export-led growth is a long-run phenomenon, in the sense that export-promotion strategies adopted today have their strongest effect after eight to 16 years. In other cases the opposite is true; exports have their greatest influence in the short run (less than four years). It may also be the case that a country may exhibit a strong export-led growth effect at particular frequencies (i.e., time horizon), even though there may be little evidence of the effect in the overall measure.

While we feel that these findings are interesting in themselves, they also provide a set of facts that may serve as a guide to theorists who are currently working to develop better theories of economic growth.

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from the NBER (nber.harvard.edu). Since this paper was written, a further update (Mark 5.6) has been released and is also available via ftp.

3 The variable OPEN (exports + imports as % of CGDP) is given in the Penn-World Table, and the current net foreign balance (cnfb; as a percentage of CGDP) can be obtained by the formula $100 - cc - ci - cg = cnfb$, where cc, ci, and cg are the percentage shares of consumption, investment and government spending, respectively, in CGDP. Then exports/CGDP = (OPEN + cnfb)/200, and imports/CGDP = (OPEN − cnfb)/200.

4 Exceptions are Serletis (1992), who includes imports; Ghartey (1993), who includes the terms of trade and the capital stock; and Kunst and Marin (1989), who study the causal relationships between productivity, export growth, the terms of trade and OECD output.

2 The State of the Evidence

2.1 *Existing Evidence*

Existing tests for the presence of export-led growth generally rely on the concept of Granger causality.[5] That is, it is customary to check whether exports help predict output once historical output has been taken into account. More specifically, let x_t denote exports and y_t denote output. Then estimate the following two equations by ordinary least squares:

$$\begin{aligned} x_t &= \sum_{j=1}^{p} a_j x_{t-j} + \sum_{j=1}^{p} b_j y_{t-j} + u_t \\ y_t &= \sum_{j=1}^{p} c_j x_{t-j} + \sum_{j=1}^{p} d_j y_{t-j} + v_t \end{aligned} \tag{1}$$

and test the null hypotheses

$$\begin{aligned} &H_1\colon c_j = 0\ ,\quad j = 1, \ldots, p, \text{ exports fail to Granger-cause (help predict) output;} \\ &H_2\colon b_j = 0\ ,\quad j = 1, \ldots, p, \text{ output fail to Granger-cause (help predict) exports}^6. \end{aligned} \tag{2}$$

If neither hypothesis is rejected, then exports and output are causally independent, whereas if both are rejected, there is bi-directional causality between the two.[7]

Table 1 lists several recent time-series studies of export-led growth, together with their methods, data sources and results. It is readily apparent that since the seminal paper of Jung and Marshall (1985), many refinements have been used in assessing the empirical evidence for export-led growth. These refinements include modifications of the standard Granger causality test, including tests for optimal lag length (Chow, 1987; Darrat, 1987; Kunst and Marin, 1989; Ahmad and Kwan, 1991; Bahmani-Oskooee et al, 1991; Serletis, 1992; Marin, 1992; Ghartey, 1993; Oxley, 1993), tests for nonstationarity and/or cointegration between the variables (Afxentiou and Serletis, 1991; Serletis; Oxley), and including

[5] The remainder of the paper focuses exclusively on the time-series approach to export-led growth, as opposed to the cross-sectional approach, or analyses of the determinants of growth along the lines of Barro (1991).

[6] As pointed out by several authors, the testing procedure described in (1) and (2) is valid only if x and y are (covariance) stationary time series.

[7] Many authors (including Granger, 1969) use the term "feedback" to describe the case of rejection of both null hypotheses in (2). Because we measure export-led growth using the "measures of linear feedback" introduced by Geweke (1982, 1984), we use the term "bidirectional causality" here to avoid confusion.

Table 1. Previous time-series studies of export-led growth

Author(s)[a]	Method		Variables and Sources	Sample	Results[b]
	Causality	Lag Length			
Jung & Marshall (1985)	Granger-causality (GC)	–	Real GDP, real exports *International Financial Statistics* (IFS)	37 Less Developed Countries (LDCs)	$x \rightarrow y$ in Indonesia, Egypt, Costa Rica and Ecuador
Chow (1987)	Sims's version of GC	–	Manufactured exports, manufacturing output; from *Yearbook of International Trade Statistics*, *Yearbook of National Account Statistics*, *Taiwan Statistical Data Book*, *Key Indicators of Developing Member Countries of Asian Development Bank*	Argentina, Brazil, Hong Kong, Israel, Korea, Mexico, Singapore, Taiwan	No causality in Argentina; $x \rightarrow y$ in Mexico; $x \leftrightarrow y$ in all others
Darrat (1987)	White (1980)	No formal tests; up to 4 lags examined	Growth rates of real GDP and real exports, from IFS and *World Development Report*	Korea, Taiwan, Singapore, Hong Kong	$x \rightarrow y$ in Korea
Ram (1987)	Times series regression; aggregate production function specification, incorporating possible export externalities		Real GDP, exports, investment share, population growth; from World Bank's *World Tables* (WT)	88 LDCs	$x \rightarrow y$ in 38 or 37 countries (depending on specific model being estimated); positive but insignificant relationship in another 35 or 40
Kunst & Marin (1989)	GC	2 methods: a) AIC on diag. elements of AR coefficient matrix; off-diag. elements set at 4 b) diag. elements as in a; off-diag. set by backward elimination from maximum 8 lags	Exports, terms of trade and productivity, all in manufacturing, OECD GDP	Austria	OECD GDP $\rightarrow$ Productivity

Table 1. Continued

Author(s)[a]	Method		Variables and Sources	Sample	Results[b]
	Causality	Lag Length			
Ahmad & Kwan (1991)	GC on pooled sample; AIC for lag length	Akaike Information Criterion (AIC)	Real GDP per capita, level and growth rate; real exports (total and mfd), share of mfd exports in total; from *Economic Indicators of African Development*	47 African countries	no $x \rightarrow y$ in any of several specifications; little causality overall
Bahmani-Oskooee et al (1991)	Standard GC, also measured by FPE reduction	Final Prediction Error (FPE)	Real exports and GDP (1975 prices); from IFS, *Statistical Yearbook of the Republic of China*	20 LDCs	$x \rightarrow y$ in 10 (including those for which tests conflict); unidirectional positive relationship in Nigeria & Taiwan only
Afxentiou & Serletis (1991)	GC on growth rates after unit root (Phillips-Perron) and cointegration (Engle-Yoo) tests	Schwartz Criterion (SC)	Real exports (IFS) and GNP (Summers-Heston 1988)	All countries classified as industrial by IMF (16)	$x \leftrightarrow y$ in U.S.; $y \rightarrow x$ in Norway, Canada, Japan (with 10-yr lag in Canada, Japan)
Kugler (1991)	Tests for presence of exports in cointegrating relationship, using Johansen/Juselius procedure ADF for stationarity	AIC	Real GDP (GNP for US), private consumption, investment and exports; from OECD	US, Germany, Japan, UK, France, Switzerland	Exports enter cointegrating vector only in Germany and France
Marin (1992)	GC	Bayesian Information Criterion (BIC)	As in Kunst & Marin (1989)	Germany, U.K., U.S., Japan	$x \rightarrow y$ for all four, but little impact as measured by sum of AR coefficients
Serletis (1992)	GC after Phillips-Perron tests for unit roots, Engle-Granger tests for cointegration	SC	Exports, imports, GNP; from Urquhart (1988)	Canada	$x \rightarrow y$ except for post-WWII period

Bahmani-Oskooee and Alse (1993)	Regression analysis of error-correction model, after ADF *for stationarity*, and ADF and CRDW *for cointegration*		Real exports and income; quarterly data constructed from annual IFS figures	Colombia, Greece, Korea, Malaysia, Pakistan, Philippines, Singapore, South Africa, Thailand	$x \leftrightarrow y$ for all but Malaysia (x and y not cointegrated in Malaysia)
Dodaro (1993)	GC	Set at 2 lags	Real GDP, exports of goods and non-factor services; from WT	87 LDCs	$x \rightarrow y$ *(positive effect) in* 7; $y \rightarrow x$ (positive effect) in 13
Ghartey (1993)	FPE, Hsiao (1979)	FPE, BIC	Exports, GNP, capital stock, terms of trade; from *Survey of Current Business* (US); *Quarterly National Income Statistics, Monthly Statistics of Exports and Imports*, and *Financial Statistics, Taiwan District* (Taiwan); *Dept. of National Accounts, Economic Research Institute*, and *Economic Planning Agency* (Japan)	U.S., Japan, Taiwan	$x \rightarrow y$ in Taiwan, $y \rightarrow x$ in U.S., terms of trade $\rightarrow x$ in Japan
Oxley (1993)	Modified Wald test (Schmidt, 1976) after ADF and Johansen tests for unit roots & cointegration	FPE	Real GDP, exports (1914 prices); from Nunes et al (1989)	Portugal	$y \rightarrow x$
Ukpolo (1994)	Time series regression of output on disaggregated exports		Real GDP; exports of fuel, non-fuel primary products, and manufactures; sizes of public and private sectors, from World Bank	Congo Republic, Kenya, Morrocco, Nigeria, Senegal, Sierra Leone, Tanzania, Togo	$x \rightarrow y$ for non-fuel primary products

[a] See the cited works for specific details regarding methods, *years of data sources; etc.*

[b] x is the export variable, y is the income variable (both vary across studies); arrows *denote directions of causality*

other variables besides exports and growth (Kunst and Marin; Serletis; Marin; Ghartey). Rather than present an exhaustive comparison of the results of all of these papers, we summarize some of the major differences below.

In their work on causality and export-led growth, Jung and Marshall (1985) analyze the relationship between the growth rate of real exports and the growth rate of real output, for 37 developing countries. Depending on the outcome of Granger causality tests, as described above, they then characterize the countries in their sample as exhibiting one of four causal patterns: Export Promotion (EP, what we call export-led growth), Internally Generated Exports (IGE), Export-Reducing Growth (ERG), or Growth-Reducing Exports (GRE). This characterization is made on the basis of the sign of the sum of the coefficients on lags of the causal variable in the equation for the dependent variable. Jung and Marshall find evidence for the export-led growth hypothesis in only four of the 37 countries: Indonesia, Egypt, Costa Rica and Ecuador.

Chow (1987) performs a similar analysis on eight of the most successful export-oriented newly industrialized countries (NICs), using the growth rate of manufacturing output as a measure of industrial development. With two exceptions, Chow finds bi-directional causality in each country.[8] Direct comparisons with Jung and Marshall's results are hampered by the fact that Chow does not attempt to determine the sign of the relationship (i.e., whether export growth causes positive or negative output growth), as well as by the use of different variables. However, results for four of the six countries common to the two samples (Brazil, Korea, Mexico and Taiwan) differ across the studies. Jung and Marshall find no significant causality in Brazil or Mexico, and causality only from output to exports in Korea and Taiwan. The two papers draw similar inferences about the existence of causality in Israel, although Jung and Marshall argue that the effect is negative in each direction.

Unlike these two papers, Serletis (1992) also includes the growth of imports in his analysis. In Canadian data from 1870–1985, he finds that export growth causes GNP growth over the full sample and in the pre-WWII subsample. At the same time, he finds no evidence that import growth causes either export growth or income growth.

Marin (1992) presents a vector autoregressive (VAR) analysis of data for Germany, the United Kingdom, the United States and Japan. Using quarterly data for manufactured exports, the terms of trade, OECD output and labor productivity, Marin performs preliminary tests for the cointegration of exports and productivity (i.e., tests of whether the two variables have a long-run equilibrium relationship). Although he finds no conclusive evidence of cointegration between these two variables, he does find evidence of a cointegrating relationship between exports, productivity and the terms of trade, except for the UK.

[8] Note that Chow uses Sims's version of the Granger-causality test; 3 *future values* (leads) of each variable are included in the regression equations (1), along with 3 lags.

Marin's Granger-causality tests support the export-led growth hypothesis for the four countries in his study, but he finds that the "quantitative impact of exports on productivity seems to be negligible," (Marin, 1992, p. 685) on the basis of the sum of the autoregressive coefficients on lagged values of exports in the productivity equation.

Other large-scale studies reach divergent conclusions regarding export-led growth. Bahmani-Oskooee et al. (1991) examine 20 less-developed countries (LDCs), all of which are also studied by Jung and Marshall. Although they find evidence of a causal relationship between exports and growth in half of these countries (including cases in which their two test procedures gave different results), they find evidence of a unidirectional positive relationship[9] only in Nigeria and Taiwan. Like Jung and Marshall, they find evidence for export-led growth in Indonesia. However, the two papers reach different conclusions for Korea, Taiwan and Thailand (export-led growth in Bahmani-Oskooee et al; export-reducing growth, causality from growth to exports, and internally generated exports, respectively, in Jung and Marshall).

Afxentiou and Serletis (1991) find no export-led growth in any of the 16 industrial countries in their sample. Although they find unidirectional causality from output growth to export growth in Norway, Canada and Japan, there is a ten-year lag in the effect for the latter two countries. The only other causal relationship they find is bidirectional causality in the U.S.

The clear message from table 1 is that a great variety of techniques, data sets and country groups have been employed in empirical assessments of the export-led growth hypothesis, with an equally wide variety of results. Our main motivation in undertaking the present study was a desire to reconcile these diverse results, or at least to discover why they could not be reconciled. Moreover, our use of the Summers-Heston (1991) data set and Geweke's (1984) measures of linear feedback also illustrates the value of *measuring* any export-led growth effects, as opposed to simply detecting them.

In interpreting the results below, it will prove useful to be precise about how we translate patterns of causality into statements about export-led growth. When used in this paper, "export-led growth" means that there exists a causal ordering (either direct or indirect) from export growth to income growth, with no "return loop" to export growth. For example, the bidirectional causality found by Chow does not meet our definition of export-led growth, since output growth Granger-causes export growth. Clearly, our definition is not unique. However, we feel that it is the best in terms of emphasizing the extent to which export growth *leads* income growth.[10]

Broadly speaking, the results of bivariate Granger causality tests we performed with the Summers-Heston data are consistent with those of other

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9 Based on the sign of the sum of the autoregressive coefficients, as in Jung and Marshall (1985) and Marin (1992).

10 Theoretical reasons for exports leading growth are summarized in, *inter alia*, Jung and Marshall (1985, p. 3), or Kunst and Marin (1989, p. 699).

authors, who find little evidence of export-led growth.[11] Of the 126 countries for which results are available, only 16 display evidence of export-led growth (i.e., unidirectional causality from exports to income) at the 10 percent significance level.[12] There is evidence of "growth-led exports" in 14 countries, while only three appear to have bidirectional causality between exports and income. Thus, the majority of the world's countries exhibit no clear causal ordering between exports and income. However, as we argue below, the results of bivariate Granger causality tests do not provide a comprehensive picture of the evidence regarding export-led growth.

In order to conserve space and simplify exposition, the body of this paper presents results only for a subset of countries in the Summers-Heston data set. This subset includes Hong Kong, Indonesia, Japan, (the Republic of) Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand: results for all countries in the sample are collected in an unpublished appendix.[13] We focus on these countries in particular because they are often cited as instances of the success of export promotion strategies.

Table 2 presents the results of the bivariate Granger causality analysis for our subset of countries. Here, evidence in favour of the export-led growth hypothesis consists of export growth (x) causing income growth (y), by which we mean that the null hypothesis of no causality from x to y is rejected at the 10 percent critical level, but not vice versa, by which we mean the null of no causality from y to x is *not* rejected at the 10 percent level. Columns 3 and 5 present marginal significance levels for the Granger-causality tests, while columns 7 and 8 contain the same information for the tests of no (unconditional) linear feedback in the sense of Geweke (1982). Further discussion of Geweke's linear feedback measures is given below. Causal inferences based on each of these tests are given in the final two columns of the table.

In columns 4 and 6 of table 2, we report the average response of each variable to a unit shock in the other, over a 16-year period.[14] This provides a means of assessing the sign of the relationship between export growth and output

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[11] An appendix containing a complete set of our results for all 126 countries, as well as the details of the computation of the conditional linear feedback statistics reported below, is available via anonymous ftp from iks.biz.uiowa.edu. The file is called "RSW95.zip" and is in the \pub directory.

[12] The majority of the 24 missing countries have insufficient data for one or more variables to allow estimation. The major oil-exporting countries (e.g., Saudi Arabia, Kuwait, the United Arab Emirates) have been excluded from Mark 5.5 of the data set.

[13] Tables 4 and 7 below include additional countries, in order to illustrate specific points. The appendix is available upon request from the authors. See note 11.

[14] Doing this requires identifying economic shocks (to exports, to income) from statistical residuals. We follow Sims (1980) and use a World-causal chain scheme whereby the export shock is the residual in the export equation and the output shock is that part of the output residual which is orthogonal to (uncorrelated with) the export shock (i.e., exports are ordered "first"). We do not consider alternative identifying restrictions or causal orderings in this paper; for this reason, the results should be taken as suggestive.

Table 2. Measures of export-led growth, 2-variable system

COUNTRY	DATA	$x \rightarrow y$[b] GC	impulse[c]	$y \rightarrow x$[b] GC	impulse[c]	$x \rightarrow y$[b] LF	$y \rightarrow x$[b] LF	OPEN[d]	Inference[e] (GC)	Inference[e] (LF)
HONG KONG	1960–90	0.4590	0.0015	0.2624	0.0002	0.3875	0.1962	268.22	0	0
INDONESIA	1960–90	0.7174	0.0051	0.8582	−0.0032	0.6675	0.8302	50.92		
JAPAN	1950–90	0.8530	0.0001	0.0135	0.0079	0.8240	0.0053	21.58	$y \rightarrow x$	$y \rightarrow x$
REP. OF KOREA	1953–89	0.3200	0.0022	0.1242	−0.0014	0.2470	0.0773	65.72 (89)	0	$y \rightarrow x$
MALAYSIA	1955–90	0.9881	0.0067	0.9896	−0.0003	0.9855	0.9873	156.06		
PHILIPPINES	1950–90	0.7707	0.0011	0.0165	0.0034	0.7283	0.0068	61.16	$y \rightarrow x$	$y \rightarrow x$
SINGAPORE	1960–90	0.6000	0.0055	0.5726	0.0010	0.5369	0.5072	373.83	0	0
TAIWAN	1951–90	0.0110	0.0033	0.1215	−0.0048	0.0041	0.0769	89.43	$x \rightarrow y$	$x \leftrightarrow y$
THAILAND	1950–90	0.2031	0.0022	0.1903	−0.0014	0.1436	0.1327	78.43		

[a] x is the growth rate of exports; y is the growth rate of income (total GDP in current international dollars; see Summers and Heston, 1991).
[b] Marginal significance level for the null hypothesis of no unidirectional causality (Granger causality F-tests in columns 3 and 5, unconditional linear feedback in columns 7 and 8).
[c] Average impulse response over 16 year period.
[d] Exports plus imports as a percentage of CGDP (Summers and Heston, 1991), data for 1990 unless otherwise indicdated.
[e] Inference regarding causal ordering, at 10% level. GC = Granger causality, LF = linear feedback, "→" = unidirectional causality, "↔" = bidirectional causality.

growth.[15] For example, a unit shock to export growth in Korea (i.e., a one-time doubling of exports) leads to an average increase in the rate of income growth of 0.22 percent per year for 16 years. Doubling income leads to a drop in export growth of 0.14 percent per year over the same period.[16] Of all the countries in our study that display evidence of export-led growth, none has a negative response of income to export shocks. Column 9 in the table presents the variable OPEN from the Summers-Heston (1991) data set, which is the share of trade in CGDP. The values reported are for the most recent year available (1990 unless indicated).

2.2 *The Role of Import Growth*

With one exception, previous studies of export-led growth have not addressed the role of import growth in the export-income relationship. Serletis (1992) includes lagged values of import growth in his examination of Canadian data, and finds no Granger causality from import growth to either income growth or export growth. That is, letting m_t denote imports, he estimated equations of the form

$$\begin{aligned} x_t &= \sum_{i=1}^{p} a_j x_{t-j} + \sum_{i=1}^{p} b_j y_{t-j} + \sum_{i=1}^{p} f_j m_{t-j} + u_t \\ y_t &= \sum_{i=1}^{p} c_j x_{t-j} + \sum_{i=1}^{p} d_j y_{t-j} + \sum_{i=1}^{p} g_j m_{t-j} + v_t \end{aligned} \tag{3}$$

and tested the null hypotheses

$$\begin{aligned} &H_1\colon c_j = 0\ ,\quad j = 1, \ldots, p \text{ (exports fail to Granger-cause output in the three-variable universe)} \\ &H_2\colon b_j = 0\ ,\quad j = 1, \ldots, p \text{ (output fail to Granger-cause exports in the three-variable universe),} \end{aligned} \tag{4}$$

as well as similar hypotheses regarding the f_j and g_j. Table 3 reports the results of Granger causality tests in this three-variable system, for the countries listed in table 2.[17]

[15] Using the sign of the sum of the autoregressive coefficients, as is done in Jung and Marshall (1985), Marin (1992) and Bahmani-Oskooee et al. (1991), amounts to examining the impulse response at an infinite horizon.

[16] The impulse response analysis discussed here differs from many such applications, in that we do not (necessarily) think of the changes in growth rates as being induced by policy changes. Rather, it is our analogue to summing our estimated autoregressive coefficients (see the previous footnote).

[17] Note that this version of Granger causality tests exclusion restrictions on each equation separately, rather than in a full three-variable VAR. The conditional linear feedback measures reported below are based on such a trivariate system. This difference, combined with sampling error, accounts for the disparity in results between our Granger causality and conditional linear feedback tests.

Table 3. Granger-causality tests, 3-variable system

Country	Data	$x \to y$[a,b]	$y \to x$	$x \to m$	$y \to m$	$m \to x$	$m \to y$
HONG KONG	1960–90	0.1562	0.1557	0.3946	0.0652	0.3108	0.2722
INDONESIA	1960–90	0.1442	0.8001	0.8710	0.7633	0.9159	0.1774
JAPAN	1950–90	0.6564	0.0105	0.0574	0.0823	0.0093	0.7552
REP. OF KOREA	1953–89	0.0406	0.2763	0.0091	0.3866	0.0454	0.0846
MALAYSIA	1955–90	0.3609	0.5146	0.0889	0.3727	0.0588	0.0070
PHILIPPINES	1950–90	0.3136	0.0029	0.0565	0.0001	0.1117	0.1698
SINGAPORE	1960–90	0.9162	0.8546	0.3814	0.6479	0.2972	0.7786
TAIWAN	1951–90	0.0953	0.1527	0.3351	0.7924	0.8939	0.8371
THAILAND	1950–90	0.5530	0.1458	0.1137	0.1776	0.4905	0.6979

[a] x is the growth rate of exports; m is the growth rate of imports; y is the growth rate of income (total GDP in current international dollars; see Summers and Heston, 1991).
[b] Marginal significance level for the null hypothesis of no unidirectional causality.

Table 4 demonstrates the importance of import growth in the causal ordering. Omitting imports can result in both "type I" and "type II" errors – spurious rejection of export-led growth as well as spurious detection of it. In columns 2 through 7 we present the marginal significance levels for the Granger causality F-tests in two systems: the two-variable system of export growth and income growth, and a three-variable system with import growth (m) included. Comparing the two rows for each of the six countries listed, we find that the omission of import growth can mask significant causality between exports and income, or may cause spurious causality.[18] For examples of the former, consider Ghana, South Africa and Korea. In the two-variable system of exports and income, there is no significant causal ordering for these countries. However, the second row for each of these countries shows that there does exist a significant two-stage causal chain, running from exports to imports to income, as well as a direct exports-to-income chain. There is also evidence of bidirectional causality between exports and imports in Korea.

In Japan, the "growth-led exports" phenomenon apparently operates both directly and indirectly through imports. Again, there is evidence of bidirectional causality between exports and imports.

The remaining countries in table 4 provide evidence of the possibility that causal inferences in the two-variable system may be due to omitted variable bias. In each of these countries, significant causality in the first row disappears in the second. The "growth-led exports" inference for Argentina does not change, but it is apparently an indirect causal chain, from income to imports to exports (a "reverse two-gap model"). By contrast, the (bivariate) export-led growth evidence for Peru is reversed completely in the trivariate system, re-

[18] For simplicity's sake, we will use the term "exports" instead of "growth rate of exports," and so on. When we wish to refer to the *level* of any variable we will say so explicitly.

Table 4. Granger-causal orderings, 2-variable vs 3-variable systems

	$x \rightarrow y$	$y \rightarrow x$	$x \rightarrow m$	$y \rightarrow m$	$m \rightarrow x$	$m \rightarrow y$
GHANA	0.2309	0.8141				
	0.0068	0.8096	0.0521	0.3552	0.6667	0.0226
SOUTH AFRICA	0.2249	0.4357				
	0.0177	0.6549	0.0314	0.0258	0.1103	0.0017
ARGENTINA	0.6289	0.0144				
	0.5029	0.3726	0.3530	0.0261	0.0959	0.4956
COLOMBIA	0.0641	0.0340				
	0.0216	0.5229	0.0783	0.5796	0.4980	0.2218
PERU	0.0146	0.9991				
	0.1493	0.2891	0.4988	0.0785	0.0074	0.9612
SWEDEN	0.0079	0.6523				
	0.2723	0.7658	0.0003	0.0220	0.0344	0.4092
JAPAN	0.8530	0.0135				
	0.6564	0.0105	0.0574	0.0823	0.0093	0.7552
REP. OF KOREA	0.3200	0.1242				
	0.0406	0.2763	0.0091	0.3866	0.0454	0.0846

[a] Entries are marginal significance levels for null hypotheses of no Granger causality. Notation parallels that of Table 3.

vealing an indirect link similar to that in Argentina. In Colombia, exports appear to cause both income and imports, while in Sweden there is evidence of bidirectional causality between exports and imports, with imports being caused in turn by income.

As we have seen, imports may play the role of a confounding variable in causal ordering (i.e., imports affect both income and exports). Failure to account for imports can therefore produce misleading results. In the remainder of this paper, all our results explicitly account for imports.

2.3 *Perspective on the Evidence*

There are two major problems with the use of Granger causality tests in searching for export-led growth. The first concerns the difference between statistical significance of the Granger causality F-tests and the strength of the relationship between exports and income. Marginal significance levels (or p-values) cannot be interpreted as indicators of the strength or weakness of any causal relationship. While p-values are certainly of interest, they are arguably of secondary importance to a consistent measurement of the causal relationship itself.

The second major problem is the limited time horizon of Granger causality tests. A finding that exports Granger-cause income means only that the variance in the *one-step-ahead* forecast error, made from predicting income linearly using its own past, is reduced when lags of exports are included. There is no a priori reason to think that any causal relationship between exports and imports must necessarily become apparent in a year.[19]

We present two ways of addressing these problems. The first is the decomposition of forecast error variance, and the second uses the measures of conditional linear feedback developed by Geweke (1984). Both methods provide measurements of the strength of feedback between exports and income, which are comparable across countries. These measures also allow for a flexible time horizon. These techniques have been used for some time in the empirical macroeconomics literature, but to our knowledge have not previously been applied to the study of export-led growth.

3 New Measures of Export-Led Growth

3.1 Forecast Error Variance Decomposition

The forecast error variance decomposition (FEVD) is a way to answer the question, "How much of the variance in forecast errors of future income growth can be attributed to innovations in export growth?" This technique is standard in the VAR approach; for details, the reader is referred to Doan (1992), Sims (1980), etc.

Because the FEVD is based on the decomposition of the covariance matrix of the three-variable vector autoregression (VAR), and because this decomposition is not unique, the fraction of the forecast error in income attributable to exports generally changes depending on the ordering of the variables. In order to set a criterion for export-led growth, we seek countries in which exports explain at least 25 percent of the variance of the five-year-ahead forecast of income, when exports are placed second in the decomposition ordering. In other words, this ordering gives imports the "first shot" at explaining the variance of income forecasts. We chose a five-year horizon based on evidence for a world business cycle of roughly that duration (Riezman and Whiteman, 1991). Countries that meet our criterion are thus the ones in which the role of export growth is particularly strong in explaining income growth.

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[19] This study, like most others, uses annual data.

Table 5. Five-year forecast error variance decomposition

Country	$x - m - y$[a]	$m - x - y$[a]	% y[b]
HONG KONG	18.97	11.60	67.93
INDONESIA	22.88	44.60	44.53
JAPAN	2.85	2.82	94.37
REP. OF KOREA	17.43	24.38	63.35
MALAYSIA	67.18	19.48	21.29
PHILIPPINES	3.47	3.49	89.61
SINGAPORE	56.61	4.65	42.33
TAIWAN	58.18	17.58	39.16
THAILAND	22.23	13.04	59.08

[a] Entries are the percent of the five-year forecast error in income which is attributable to innovations in exports, for the given ordering.
[b] Percentage of income forecast error variance attributable to income innovations.

Table 5 reports FEVD results for the Wold-causal chain orderings $x - m - y$ and $m - x - y$.[20] The last column of the table reports the fraction of income forecast error variance explained by income innovations. This column gives an indication of the degree to which income growth is exogenous with respect to export growth and import growth.

3.2 *Measures of Linear Feedback*

Unconditional linear feedback: The linear feedback measures developed by Geweke (1982, 1984) provide an alternative to both Granger causality tests and the FEVD. These statistics are designed not just to *detect* a feedback relationship (i.e., a causal ordering) but to provide a measure of its *strength.* While the Granger causality statistics simply reflect whether forecast error variance is reduced by adding another variable, it is useful to consider the extent of this reduction. Let $F_{x \to y}$ denote the measure of linear feedback from exports to income. The reduction in the variance of the (one-step-ahead) mean squared income forecast error, when exports are included in the regression, is given by $-\exp(-F_{x \to y})$. Pierce (1982) notes that $1 - \exp(-F_{x \to y})$ can be interpreted analogously to the coefficient of determination (R^2) in ordinary regression. As noted by Geweke (1982), $F_{x \to y}$ has all the features one expects in a measure – it is positive, monotone, and (in its R^2 form) lies between zero and unity. The absence of Granger causality from x to y is equivalent to $F_{x \to y} = 0$. Furthermore, these measures are invariant under filtering of the time series by (possibly

[20] See footnote 10 above.

different) invertible lag operators. Finally, when the data are measured in comparable units (e.g., the growth rates used here) this measure is comparable across countries.

We report the marginal significance levels for the test of (unconditional) linear feedback in Table 2 (columns 7 and 8), along with the bivariate Granger-causality results. These statistics are monotonic transformations of the F statistics computed in Granger causality tests for a system of (possibly vector-valued) time series $\mathbf{u}$ and $\mathbf{v}$. When multiplied by the sample size, these measures have an asymptotic chi-square distribution, with degrees of freedom equal to the number of lags if $\mathbf{u}$ and $\mathbf{v}$ are univariate.[21] The two measures of causality are generally consistent. Of the 33 countries that exhibit a significant Granger-causal ordering, 31 have the same ordering as measured by Geweke's linear feedback measures. A causal ordering is somewhat more likely using Geweke's measures; 13 countries have evidence of "Geweke feedback" but no Granger causality. Only two countries exhibit significant Granger causality but no linear feedback.[22] In addition, for the countries that pass one test but not the other, the marginal significance levels are not "off" by very much.

Conditional linear feedback: When income is forecast using lags of itself and imports, adding lagged values of exports reduces forecast error variance by an amount given by the same formula as above, but using $F_{x \to y|m}$, the measure of *conditional* linear feedback from exports to income (Geweke, 1984). Both the conditional and unconditional measures can be decomposed by frequency in order to examine the nature of the causal relationship at various time horizons. This feature is discussed in the next section.

The great attraction of the measures of *conditional* linear feedback is that they allow us to focus on the causal relationship between exports and output, while at the same time controlling for imports. This helps us avoid the "omitted variables" situation described in section 2.2. In contrast to the unconditional linear feedback measures however, there is no tractable asymptotic distribution theory available for the conditional measures. We therefore use Monte Carlo integration to compute Bayesian posterior distributions for these statistics (computational details are given in the Appendix, along with our non-informative prior distribution).

Table 6 presents the conditional linear feedback statistics for our subset of nine countries. (Results for all countries are presented table 9.) The conditional linear feedback measures in table 6 are expressed in their "R^2" version for ease of exposition. Thus, point estimates indicate that for Hong Kong, roughly

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[21] When $\mathbf{u}$ and $\mathbf{v}$ are multivariate, the degrees of freedom is equal to (number of lags) $*$ (dimension of $\mathbf{u}$) $*$ (dimension of $\mathbf{v}$). See Geweke (1982, 1984) for a more complete description of these measures.

[22] Actually, these two countries (Syria and Taiwan) show evidence of significant but *different* causal orderings under the two measures: export-led growth under Granger causality, but bidirectional causality under Geweke's measures. Apart from these two, the "Granger causal set" of countries is a proper subset of the "Geweke feedback set."

19 percent of the one-step ahead forecast error variance for income growth is explained by export growth, after the effects of import growth have been accounted for. Conversely, 25 percent of the forecast error variance for export growth is explained by income growth.

There is evidence for export-led growth when the bulk of the $F_{x \to y|m}$ distribution lies to the right of the $F_{y \to x|m}$ distribution. Note that in Taiwan, the 90$^{\text{th}}$ percentile of the distribution of $F_{y \to x|m}$ lies below the 10$^{\text{th}}$ percentile of the $F_{x \to y|m}$ distribution. We believe this constitutes strong evidence of export-led growth, and use this condition as our preferred criterion for assessing the conditional linear feedback estimates.

This criterion for export-led growth is met in 19 of the countries in our sample.[23] Comparable evidence in favor of "growth-led exports" is present in 10 countries, including Japan and Korea in table 6.[24] It therefore seems that the export-led growth hypothesis is somewhat more likely than its converse.

Expressing the feedback measures in terms of percentage of forecast error variance explained is also useful in cases where no clear causal ordering is present. For example, although a causal ordering is indicated in only three countries in table 6, point estimates of the predictive power of exports in explaining income growth exceed the converse in six of the nine.[25] Moreover, feedback from income growth to export growth is stronger for these nine countries than that for the sample overall: point estimates of the R^2 version of $F_{y \to x|m}$ are 40 percent for the countries in table 6, and 34 percent for all 126 countries. Comparable figures for $F_{x \to y|m}$ are 36 percent in both groups. It would therefore seem that although the conditional feedback measures provide weak support for export-led growth in these countries, the strength of the causal relationship differs little, on average, from the world as a whole.

An interesting pattern emerges when our results are compared with those of Jung and Marshall (1985), Bahmani-Oskooee et al (1991), and Afxentiou and Serletis (1992). First, we tend to find evidence of export-led growth more often than these authors. Using our weaker criterion, we find export-led growth in nine of the 37 countries studied by Jung and Marshall (compared to their four); in five of 20 studied by Bahmani-Oskooee et al (they find three); and in three of 16 studied by Afxentiou and Serletis (who found one). Second, although there are instances where our conclusions match those of these other authors, our results differ in general. For example, we confirm Jung and Marshall's findings in their four "export promotion" countries (Indonesia, Egypt, Costa Rica, Ecua-

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[23] An alternative criterion would be for $\hat{F}_{x \to y|m} > F^{(90)}_{y \to x|m}$ and $\hat{F}_{y \to x|m} < F^{(10)}_{x \to y|m}$ where $\hat{F}$ and $F^{(j)}$ denote the point estimate and the j^{th} posterior percentile, respectively, of the indicated measure of feedback. This weaker criterion has more of the flavour of a standard one-sided hypothesis test. Measured in this way, 30 countries (24% of the sample) show evidence of export-led growth.

[24] Or 25 (20% of the sample), using the weaker criterion of footnote 18.

[25] "Point estimates" are computed using the posterior mean values of VAR parameters. Also, note that Indonesia, the Philippines and Singapore narrowly miss satisfying our weaker criterion; the required difference in posterior deciles is less than 1% in each case.

Table 6. Linear feedback conditional on imports (R^2 measure)

COUNTRY	DATA	$1 - \exp(-F_{x \to y\|m})$[a] 10th	50th	90th	pt. est.	$1 - \exp(-F_{y \to x\|m})$[a] 10th	50th	90th	pt. est.	Inference[b]
HONG KONG	1960–90	0.1475	0.2521	0.4047	0.1858	0.1892	0.2752	0.3803	0.2493	
INDONESIA	1960–90	0.1354	0.2832	0.4809	0.2075	0.0243	0.0850	0.2100	0.0274	
JAPAN	1950–90	0.0417	0.0929	0.2176	0.0319	0.6121	0.7284	0.8070	0.7468	$y \to x$
REP. OF KOREA	1953–89	0.2134	0.3296	0.4518	0.2737	0.5205	0.6209	0.6980	0.6439	$y \to x$
MALAYSIA	1955–90	0.4703	0.6033	0.7176	0.6081	0.3922	0.5324	0.6278	0.5308	
PHILIPPINES	1950–90	0.3630	0.4364	0.4961	0.4494	0.3266	0.3815	0.4474	0.3689	
SINGAPORE	1960–90	0.3802	0.5784	0.7207	0.5638	0.1837	0.3589	0.5122	0.3877	
TAIWAN	1951–90	0.5104	0.6487	0.7380	0.6546	0.2030	0.3535	0.4686	0.3838	$x \to y$
THAILAND	1950–90	0.2187	0.3367	0.4457	0.2948	0.1945	0.2852	0.4250	0.2440	

[a] $F_{x \to y|m}$ is the measure of linear feedback from exports to income, conditional on imports. $F_{y \to x|m}$ is interpreted similarly. Table entries are the point estimate (pt. est.) and the 1st, 5th, and 9th deciles of the posterior distributions of $1 - \exp(-F_{x \to y|m})$. This latter quantity is analogous to the coefficient of determination (R^2) or fraction of variation explained.

[b] $x \to y$ means that the 10th posterior decile of $1 - \exp(-F_{x \to y|m})$ lies above the 90th posterior decile of $1 - \exp(-F_{y \to x|m})$. $(x \to y)$ means that the point estimate of $1 - \exp(-F_{x \to y|m})$ lies above the 90th posterior decile of $1 - \exp(-F_{y \to x|m})$, and the point estimate of $1 - \exp(-F_{y \to x|m})$ lies below the 10th posterior decile of $1 - \exp(-F_{x \to y|m})$. $y \to x$ and $(y \to x)$ are interpreted similarly.

dor),[26] but of the 27 causal inferences made by the others, we reach the same conclusion in only eight (including Ecuador and Indonesia). It could be that this is due to the fact that none of these three papers includes import growth in their analysis, or to differences in data sets, length of sample period or technique.

Additional light can be shed on our results by considering the relationship between a country's openness and the support for the export-led growth hypothesis in that country. Table 7 lists the 10 countries with the "strongest" (conditional) causal inference in each direction (i.e., from exports to income and vice versa). In measuring strength, we computed the difference between the R^2 for exports causing income and the R^2 for income causing exports. We interpret this difference as the relative strength of export-led growth, and report it as the variable RSX in table 7. We also report each country's degree of openness.

Examination of table 7 shows that openness is neither necessary nor sufficient for a causal inference between exports and income. In the 20 countries in table 7, the correlation between openness and the relative strength of exports is just 0.0883.[27] This result suggests that the success or failure of trade policies in stimulating income growth depends on more than merely increasing the *volume* of trade.[28]

3.3 The Temporal Nature of Export-Led Growth: Conditional Feedback by Frequency

A key motivation for the use of Geweke's measures of linear feedback is that these statistics may be additively decomposed by frequency. This enables us to examine not only the overall strength of a causal relationship, but also the temporal horizon over which it acts. We may therefore gain new insights into whether export-led growth is a long- or short-term phenomenon, if it is particularly strong at business cycle frequencies, etc. Details of the frequency decomposition are given in the Appendix.[29]

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[26] Ecuador is another "borderline" case, similar to the countries in footnote 22.

[27] For all 126 countries analyzed, this correlation is 0.0246, while for those for which we make a causal inference, it is 0.0654.

[28] Indeed, the fact that some of the world's most open economies are those of sub-Saharan Africa suggests that the trade-growth relationship is not a simple one.

[29] Note that this decomposition addresses a different issue than that of selecting the appropriate lag length in a standard Granger causality test. The latter is concerned with the appropriate specification of the autoregressive representation of the system; the former is derived from the moving average representation.

Table 7. Relationship between conditional linear feedback (R^2 measure) and openness

COUNTRY	$1-\exp(-F_{x\to y\mid m})$[a]	$1-\exp(-F_{y\to x\mid m})$[a]	RSX[b]	OPEN[c]	Inference[d]
EGYPT	0.7498	0.0507	0.6991	65.06	$x\to y$
NEPAL	0.8267	0.2107	0.6159	35.15	$x\to y$
URUGUAY	0.6698	0.1128	0.5570	46.54	$x\to y$
GHANA	0.5052	0.0268	0.4784	48.75	$x\to y$
RWANDA	0.6168	0.1517	0.4651	27.17	$x\to y$
MALI	0.6333	0.1704	0.4629	51.33	$x\to y$
MOROCCO	0.6355	0.2042	0.4313	56.13	$x\to y$
ICELAND	0.6594	0.2368	0.4226	72.02	$x\to y$
IRAN	0.4460	0.0269	0.4191	23.8	$x\to y$
TUNISIA	0.5785	0.1761	0.4024	90.78	$x\to y$
average	0.6321	0.1367	0.4954	51.67	–
SEYCHELLES	0.1845	0.5485	−0.3640	109.77	$y\to x$
REP. OF KOREA	0.2737	0.6439	−0.3702	65.72	$y\to x$
GUINEA-BISSEAU	0.1064	0.4873	−0.3809	78.99	$y\to x$
MALAWI	0.0439	0.4284	−0.3845	58.02	$y\to x$
CAMEROON	0.1046	0.5037	−0.3991	40.34	$(y\to x)$
ZIMABWE	0.0607	0.5213	−0.4607	64.88	$y\to x$
YEMEN	0.0952	0.6081	−0.5128	41.9	$y\to x$
ARGENTINA	0.1463	0.7765	−0.6302	20.79	$y\to x$
BANGLADESH	0.1466	0.8564	−0.7097	26.42	$y\to x$
JAPAN	0.0319	0.7468	−0.7148	21.58	$y\to x$
average	0.1194	0.6121	−0.4927	52.84	–
ρ(RSX, OPEN)[e]				0.0883	

[a] Point estimates of $1-\exp(-F_{x\to y\mid m})$ and $1-\exp(-F_{y\to x\mid m})$, as defined in table 6. Countries listed are those with the ten largest and ten smallest values for RSX.
[b] Relative strength of exports, defined as the difference between columns 2 and 3.
[c] As in table 2.
[d] $x\to y$, $(x\to y)$, $y\to x$ and $(y\to x)$ as defined in table 6.
[e] Coefficient of correlation between RSX and OPEN.

Figures 1 and 2 illustrate the usefulness of the frequency decompositions. The figures compare the conditional feedback between exports and income for Japan and Korea, respectively. According to table 6, both countries display strong evidence of growth-led exports. However, the temporal nature of the relationship is quite different, as the figures show. In Japan, feedback from exports to income is virtually nonexistent at all frequencies (figure 1a). Although the posterior medians of the various distributions are around 20 percent for cycles of 5.3 years or less, the corresponding point estimates never exceed 10 percent. Feedback from income to exports (figure 1b) is much stronger at all frequencies; point estimates increase from just under 60 percent in the very short run, to 90 percent in the long run.

In Korea, the pattern of feedback from exports to income is similar to that for Japan in the short run, with point estimates around 20 percent (figure 2a). However, feedback in this direction becomes much stronger in the long run, exceeding 80 percent in the very long run. The pattern of feedback from income to exports (figure 2b) is nearly the mirror image, with point estimates declining from 70 percent at cycles of 4.57 years to just over 10 percent at the longest cycles. Using the criteria introduced in the last section on a frequency-by-frequency basis, we find weak export-led growth (i.e., $(x \rightarrow y)$, in the notation of table 6) for Korea for cycles longer than 10.67 years. In Japan, we find at least weak growth-led exports at all cycles longer than 2.29 years, with our stronger criterion met for cycles of eight years or longer.

Although this decomposition of the conditional linear feedback measures by frequency provides a more detailed analysis of export-led growth within a particular country than was possible before, it leaves unanswered the question of *why* the export growth-income growth relationship differs across countries. The answer to this question requires a level of detailed analysis at the individual country level which is clearly beyond the scope of this paper. However, we believe this type of analysis can be used to direct future research into the appropriate *implementation* of export promotion policies in particular countries.

3.4 *The Role of Investment and Human Capital*

Given the results presented so far, a natural question arises: How do we know that our three-variable system is free of the "omitted variables" problem discussed above? In particular, what would happen if our analysis used human and/or physical capital accumulation as additional conditioning variables? Table 8 provides a partial answer. There we present values of the feedback between exports and income, conditional on human capital growth and investment growth as well as import growth, for the countries in table 6 (except Taiwan, for which we do not have a sufficiently long series for human

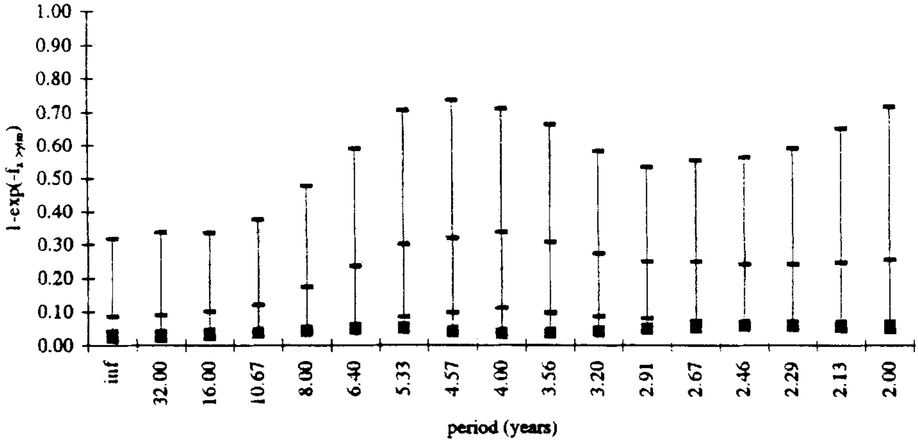

Fig. 1a. Conditional linear feedback from exports to income, Japan. Point estimates (filled squares) and 1st, 5th and 9th deciles (horizontal bars) of the posterior distribution of $1 - \exp(-f_{y>x|m})$, by frequency

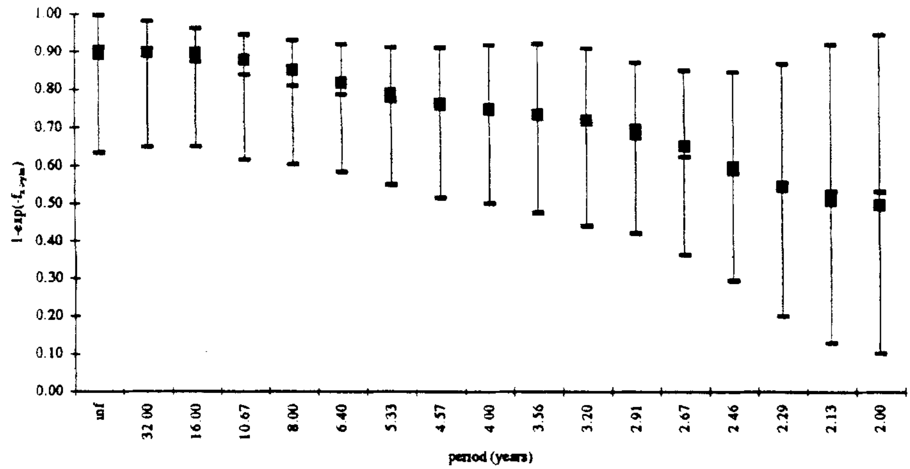

Fig. 1b. Conditional linear feedback from income to exports, Japan. Point estimates (filled squares) and 1st, 5th and 9th deciles (horizontal bars) of the posterior distribution of $1 - \exp(-f_{y>x|m})$, by frequency

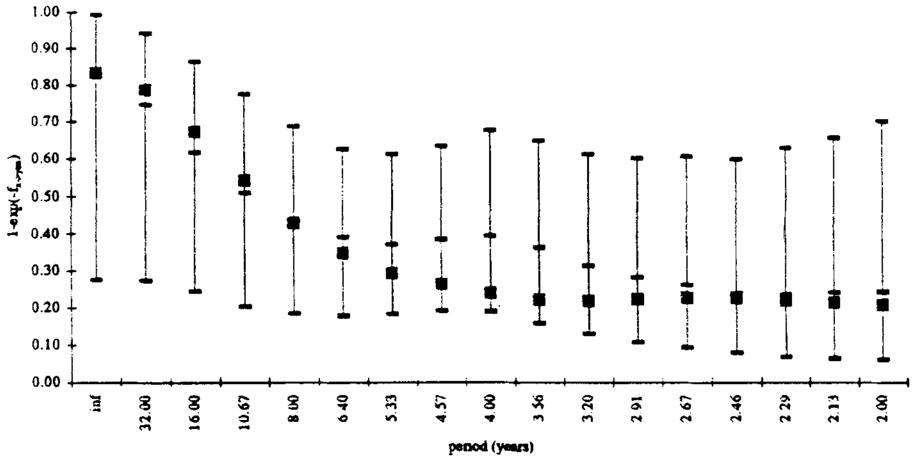

Fig. 2a. Conditional linear feedback from exports to income, Korea. Point estimates (filled squares) and 1st, 5th and 9th deciles (horizontal bars) of the posterior distribution of $1 - \exp(-f_{x>y|m})$, by frequency

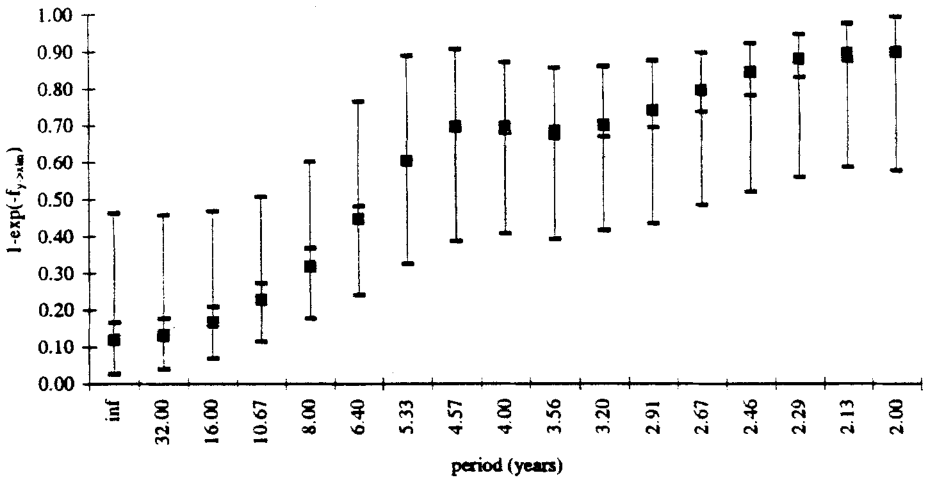

Fig. 2b. Conditional linear feedback from income to exports, Korea. Point estimates (filled squares) and 1st, 5th and 9th deciles (horizontal bars) of the posterior distribution of $1 - \exp(-f_{x>y|m})$, by frequency

capital).[30] A comparison of these two tables shows that the strength of conditional feedback in each direction increases with the addition of variables to the conditioning set. The sole exception is in Korea, where $F_{y \to x|h,i,m}$ is lower than $F_{y \to x|m}$. Evidence for growth-led exports remains strong in Japan, but weakens considerably for Korea. Our weak criterion for causal inference is now met in Indonesia (export-led growth) and Thailand (growth-led exports). Malaysia, Singapore and Thailand now have stronger feedback from income growth to export growth than vice versa; this is the reverse of the results in table 6. Table 8 therefore suggests that our results may be subject to some degree of omitted variable bias.

4 Conclusions

This paper has addressed some of the limitations of existing methods of detecting evidence for the export-led growth hypothesis. In particular, we have shown that failure to account for the role of import growth can produce misleading results in the analysis of the relationship between export growth and income growth. We have presented two alternative methods of measuring the export-income relationship, which allow us to control for the effect of imports. Use of these measures (the FEVD and conditional linear feedback) also permits us to investigate the nature of export-led growth at flexible time horizons, rather than focusing on a one-year horizon.

We believe our analysis points out several facts that need to be considered by theorists developing models of economic growth. First, export-led growth, when interpreted as a unidirectional causal ordering from exports to income, finds modest support in the Summers-Heston data set, seeming slightly more likely than the reverse ordering. Thirty of the countries in our study meet this definition of export-led growth, compared to 25 which have growth-led exports. The particular definition used (especially whether one interprets bidirectional causality as a form of export-led growth) may increase the prevalence of export-led growth still further. For example, the strength of conditional linear feedback from exports to income is stronger than feedback in the opposite direction in 65 of the 126 countries we study. Second, the role of the growth rate of imports cannot be ignored when examining the relationship between export growth

[30] The human capital measure is primary school enrolment as a percentage of primary school age children in each country (UNESCO), through 1990. Because this data is available only every five years from 1960–1985 for most countries, we use linear interpolation to estimate the data for the missing years. Investment is the total investment expenditure in CGDP (Summers and Heston, 1991).

Table 8. Linear feedback conditional on human capital, investment, and imports (R^2 measure)

COUNTRY	DATA	$1-\exp(-F_{x\to y\|h,i,m})$[a] 10th	50th	90th	pt. est.	$1-\exp(-F_{y\to x\|h,i,m})$[a] 10th	50th	90th	pt. est.	Inference[b]
HONG KONG	1960–90	0.3250	0.4841	0.6496	0.3714	0.4491	0.5596	0.6529	0.5324	
INDONESIA	1960–90	0.5472	0.6566	0.7483	0.6946	0.2473	0.4038	0.5600	0.3095	$(x \to y)$
JAPAN	1950–90	0.2080	0.3720	0.5558	0.2316	0.7629	0.8343	0.8815	0.8513	$y \to x$
REP. OF KOREA	1953–89	0.3905	0.5206	0.6588	0.5162	0.5104	0.6070	0.6970	0.6257	
MALAYSIA	1955–90	0.6174	0.7185	0.8035	0.7128	0.6816	0.7892	0.8556	0.7960	
PHILIPPINES	1950–90	0.4848	0.6006	0.7007	0.6146	0.4552	0.5519	0.6477	0.5484	
SINGAPORE	1960–90	0.5758	0.7379	0.8460	0.7535	0.5465	0.6960	0.7917	0.7733	
TAIWAN[c]	1951–90	NA	NA	NA	NA	NA	NA	NA	NA	NA
THAILAND	1950–90	0.4212	0.5443	0.6367	0.5287	0.5912	0.7007	0.7857	0.7160	$(y \to x)$

[a] $F_{x\to y|h,i,m}$ is the measure of linear feedback from exports to income, conditional on human capital, investment and imports. $F_{y\to x|h,i,m}$ is interpreted similarly. Table entries are the point estimate (pt. est.) and the 1st, 5th, and 9th deciles of the posterior distributions of $1-\exp(-F_{x\to y|h,i,m})$. This latter quantity is analogous to the coefficient of determination (R^2) or fraction of variation explained.

[b] $x \to y$, $(x \to y)$, $y \to x$ and $(y \to x)$ are defined analogously to the same type of inference in table 6.

[c] Unavailable due to the lack of a sufficiently long data series for human capital.

and income growth. Third, the effects of export growth on income growth not only vary across countries, they are not uniform over time for the same country. In particular, even in a country such as Korea, which exhibits *overall* evidence of growth-led exports, there may be time horizons at which feedback from exports to income dominates that from income to exports. This suggests that it may prove fruitful to examine the temporal nature of export-led growth more closely, in addition to its geographical occurrence.

Regarding the question raised at the beginning of the paper, "How can a country accelerate the pace of its economic development?" our results provide little in the way of policy prescriptions, nor were they intended to. They do indicate that trade and growth interact in an important and subtle way that merits further research.

Appendix

Table 9. Linear feedback between export growth and income growth, conditional on import growth

COUNTRY	DATA	$1-\exp(-F_{x\to y\mid m})$[a] 10th	50th	90th	pt est	$1-\exp(-F_{y\to x\mid m})$[a] 10th	50th	90th	pt est	Inference[b]
ALGERIA	1960–90	0.1076	0.2480	0.4129	0.2044	0.0658	0.1739	0.3089	0.1582	
ANGOLA	1960–89	0.0978	0.2163	0.3505	0.1934	0.2677	0.3896	0.4962	0.3921	$(y\to x)$
BENIN	1959–89	0.1381	0.3338	0.4964	0.3353	0.2291	0.3077	0.4294	0.3061	
BOTSWANA	1960–89	0.0791	0.1411	0.2455	0.1187	0.1150	0.1976	0.3208	0.1871	
BURKINA FASO	1959–90	0.0693	0.1278	0.2447	0.0704	0.0586	0.1093	0.1887	0.0951	
BURUNDI	1960–90	0.1194	0.2681	0.4184	0.2944	0.1255	0.2860	0.4522	0.2956	
CAMEROON	1960–90	0.0743	0.1803	0.3229	0.1046	0.2959	0.4631	0.5912	0.5037	$(y\to x)$
CAPE VERDE IS.	1960–89	0.2417	0.3407	0.4521	0.3321	0.1382	0.2585	0.4538	0.1595	
CENTRAL AFRICAN REP.	1960–90	0.0996	0.1438	0.2322	0.1141	0.2343	0.3444	0.4543	0.3437	$y\to x$
CHAD	1960–90	0.3175	0.4037	0.5021	0.4247	0.3230	0.4375	0.5397	0.4554	
COMOROS	1960–86	0.1835	0.3227	0.4794	0.3192	0.1084	0.2079	0.3466	0.1886	
CONGO	1960–90	0.1534	0.2699	0.4216	0.2109	0.1188	0.2145	0.3734	0.2043	
DJIBOUTI	1970–87	0.6343	0.7554	0.8560	0.7699	0.4957	0.6928	0.7839	0.6652	
EGYPT	1950–90	0.6509	0.7433	0.8075	0.7498	0.0443	0.0952	0.1978	0.0507	$x\to y$
ETHIOPIA	1960–86	0.1919	0.3949	0.5654	0.4126	0.4117	0.5020	0.6093	0.5004	
GABON	1960–90	0.4199	0.5622	0.6633	0.5746	0.0899	0.1795	0.2766	0.1851	$x\to y$
GAMBIA	1960–90	0.0348	0.1179	0.2656	0.0597	0.2112	0.2993	0.4056	0.2682	$(y\to x)$
GHANA	1955–89	0.3808	0.4858	0.5608	0.5052	0.0341	0.1004	0.2580	0.0268	$x\to y$
GUINEA	1959–89	0.1133	0.2098	0.3614	0.2033	0.2228	0.2735	0.3709	0.2476	
GUINEA-BISSEAU	1960–90	0.0866	0.1352	0.2228	0.1064	0.2839	0.4677	0.6134	0.4873	$y\to x$
IVORY COAST	1960–90	0.5048	0.6248	0.7159	0.6320	0.0983	0.2547	0.3982	0.2436	$x\to y$
KENYA	1950–90	0.0717	0.1460	0.2840	0.1303	0.1553	0.2340	0.3826	0.1530	
LESOTHO	1960–90	0.6106	0.7616	0.8441	0.8212	0.5621	0.6699	0.7457	0.7065	
LIBERIA	1960–86	0.3262	0.4508	0.5715	0.4580	0.2408	0.3513	0.4589	0.2956	
MADAGASCAR	1960–90	0.2550	0.4033	0.5327	0.4286	0.1636	0.2815	0.4085	0.2564	
MALAWI	1954–90	0.0433	0.1061	0.2275	0.0439	0.3076	0.4209	0.5269	0.4284	$y\to x$
MALI	1960–90	0.4787	0.6089	0.7194	0.6333	0.0869	0.1868	0.3277	0.1704	$x\to y$

MAURITANIA	1960–90	0.3281	0.4873	0.6357	0.5071	0.0706	0.1959	0.3516	0.1466	$(x \rightarrow y)$
MAURITIUS	1950–90	0.0613	0.1640	0.3058	0.0902	0.1923	0.3402	0.4765	0.3412	$(y \rightarrow x)$
MOROCCO	1950–90	0.4717	0.6038	0.7053	0.6355	0.0880	0.2084	0.3711	0.2042	$x \rightarrow y$
MOZAMBIQUE	1960–90	0.1489	0.2794	0.4277	0.2678	0.2874	0.3980	0.5111	0.3992	
NAMIBIA	1960–89	0.2309	0.3506	0.4484	0.3669	0.3562	0.4850	0.6157	0.4856	
NIGER	1960–89	0.2424	0.4024	0.5559	0.4241	0.3834	0.5328	0.6432	0.5696	
NIGERIA	1950–90	0.1264	0.2239	0.3704	0.1913	0.0187	0.0753	0.2047	0.0505	
REUNION	1960–88	0.2045	0.3324	0.4574	0.3409	0.0518	0.1399	0.2830	0.0893	$(x \rightarrow y)$
RWANDA	1960–90	0.4413	0.6187	0.7505	0.6168	0.1057	0.1786	0.3033	0.1517	$x \rightarrow y$
SENEGAL	1960–90	0.2749	0.4047	0.5203	0.4440	0.4011	0.5535	0.6917	0.5774	
SEYCHELLES	1960–89	0.1275	0.2240	0.3590	0.1845	0.4023	0.5162	0.6121	0.5485	$y \rightarrow x$
SIERRA LEONE	1961–90	0.0697	0.1663	0.3090	0.1167	0.1903	0.3379	0.4398	0.3261	$(y \rightarrow x)$
SOMALIA	1960–89	0.2129	0.3992	0.5901	0.3968	0.3556	0.4878	0.6024	0.4958	
SOUTH AFRICA	1950–90	0.5854	0.6788	0.7603	0.6842	0.3077	0.4857	0.6254	0.4937	$(x \rightarrow y)$
SUDAN	1971–90	0.5188	0.6857	0.8268	0.7555	0.3811	0.5246	0.6399	0.5391	
SWAZILAND	1960–89	0.1354	0.2405	0.4010	0.2064	0.2669	0.4086	0.5383	0.4259	$(y \rightarrow x)$
TANZANIA	1950–88	0.0613	0.1388	0.2596	0.0832	0.0857	0.2090	0.3757	0.1962	
TOGO	1960–90	0.2593	0.3949	0.5293	0.3715	0.0765	0.1823	0.3464	0.1518	$(x \rightarrow y)$
TUNISIA	1960–90	0.4596	0.5687	0.6583	0.5785	0.1580	0.2306	0.3238	0.1761	$x \rightarrow y$
UGANDA	1950–89	0.4567	0.5688	0.6731	0.5677	0.3036	0.4673	0.5951	0.4773	
ZAIRE	1950–89	0.3217	0.4257	0.5105	0.3989	0.2265	0.2969	0.4182	0.3011	
ZAMBIA	1955–90	0.1663	0.3271	0.4598	0.3414	0.0553	0.1045	0.1830	0.0578	$(x \rightarrow y)$
ZIMBABWE	1954–90	0.0400	0.1021	0.2126	0.0607	0.3446	0.4807	0.5886	0.5213	$y \rightarrow x$
BAHAMAS	1977–87	NA	NA	NA	NA	NA	NA	NA	NA	NA
BARBADOS	1960–89	0.2433	0.3803	0.4988	0.3698	0.3621	0.4988	0.6225	0.5223	
BELIZE	1985–85	NA	NA	NA	NA	NA	NA	NA	NA	NA
CANADA	1950–90	0.1031	0.1929	0.3410	0.1046	0.0527	0.1365	0.2814	0.0726	
COSTA RICA	1950–90	0.2759	0.4376	0.5661	0.4458	0.1527	0.2353	0.3691	0.2153	$(x \rightarrow y)$
DOMINICA	1985–85	NA	NA	NA	NA	NA	NA	NA	NA	NA
DOMINICAN REP.	1950–90	0.0330	0.0990	0.2399	0.0459	0.0290	0.1184	0.2603	0.0931	
EL SALVADOR	1950–90	0.1843	0.3774	0.5481	0.3609	0.4285	0.5530	0.6544	0.5611	$(y \rightarrow x)$
GRENADA	1984–90	NA	NA	NA	NA	NA	NA	NA	NA	NA
GUATEMALA	1950–90	0.1289	0.2624	0.4106	0.1804	0.0969	0.2045	0.3774	0.1558	
HAITI	1960–89	0.4229	0.5454	0.6426	0.5609	0.0835	0.2003	0.3674	0.2006	$x \rightarrow y$

Table 9. Continued

HONDURAS	1950–90	0.3157	0.4311	0.5275	0.4381	0.1782	0.3075	0.4245	0.2776	$(x \to y)$
JAMAICA	1953–89	0.2812	0.4561	0.5896	0.4407	0.3221	0.4166	0.5447	0.4212	
MEXICO	1950–90	0.3828	0.5021	0.6143	0.5203	0.3157	0.4078	0.5124	0.3977	
NICARAGUA	1960–87	NA	NA	NA	NA	NA	NA	NA	NA	NA
PANAMA	1950–90	0.1616	0.3319	0.4867	0.3222	0.1308	0.2457	0.3870	0.2390	
PUERTO RICO	1955–89	0.2970	0.5409	0.7117	0.5608	0.4970	0.5773	0.6631	0.5883	
ST. LUCIA	1985–85	NA	NA	NA	NA	NA	NA	NA	NA	NA
ST. VINCENT & GRENADA	1985–85	NA	NA	NA	NA	NA	NA	NA	NA	NA
TRINIDAD & TOBAGO	1950–90	0.2274	0.3540	0.4844	0.3710	0.3006	0.4297	0.5440	0.4472	
U.S.A.	1950–90	0.0426	0.1473	0.3163	0.1061	0.1122	0.2642	0.4387	0.2572	
ARGENTINA	1950–90	0.0753	0.1725	0.3429	0.1463	0.6437	0.7339	0.7961	0.7765	$y \to x$
BOLIVIA	1950–90	0.1344	0.2685	0.4350	0.2473	0.3213	0.4843	0.6162	0.4860	$(y \to x)$
BRAZIL	1950–90	0.0685	0.1827	0.3431	0.1521	0.2178	0.4024	0.5388	0.4089	$(y \to x)$
CHILE	1950–90	0.0729	0.1649	0.3039	0.1498	0.1816	0.3195	0.4588	0.3525	$(y \to x)$
COLOMBIA	1950–90	0.4629	0.6008	0.7366	0.5877	0.4471	0.5659	0.6518	0.5808	
ECUADOR	1950–90	0.4484	0.5716	0.6857	0.5571	0.2791	0.4302	0.5572	0.4488	
GUYANA	1950–90	NA	NA	NA	NA	NA	NA	NA	NA	NA
PARAGUAY	1950–90	0.1160	0.1891	0.3058	0.1439	0.1670	0.2801	0.4101	0.2583	
PERU	1950–90	0.4100	0.5398	0.6426	0.5501	0.4110	0.5402	0.6617	0.5591	
SURINAME	1960–89	0.4076	0.5566	0.6678	0.6036	0.1969	0.3249	0.4926	0.3216	$(x \to y)$
URUGUAY	1950–90	0.4647	0.6229	0.7371	0.6698	0.1012	0.1675	0.2936	0.1128	$x \to y$
VENEZUELA	1950–90	0.0678	0.1878	0.3612	0.1433	0.1348	0.2853	0.4399	0.2614	
BAHRAIN	1985–88	NA	NA	NA	NA	NA	NA	NA	NA	NA
BANGLADESH	1959–90	0.0702	0.1702	0.3176	0.1466	0.7999	0.8636	0.9143	0.8564	$y \to x$
BHUTAN	1985–85	NA	NA	NA	NA	NA	NA	NA	NA	NA
CHINA	1968–90	0.2694	0.4125	0.5536	0.4056	0.0334	0.0891	0.1763	0.0659	$x \to y$
HONG KONG	1960–90	0.1475	0.2521	0.4047	0.1858	0.1892	0.2752	0.3803	0.2493	
INDIA	1950–90	0.2618	0.3749	0.4873	0.3537	0.1812	0.2952	0.4174	0.3135	

INDONESIA	1960–90	0.1354	0.2832	0.4809	0.2075	0.0243	0.0850	0.2100	0.0274	
IRAN	1955–89	0.2789	0.4429	0.5960	0.4460	0.0265	0.0835	0.2139	0.0269	$x \rightarrow y$
IRAQ	1953–87	0.3038	0.4682	0.5959	0.4954	0.1365	0.2870	0.4414	0.2708	$(x \rightarrow y)$
ISRAEL	1953–90	0.4039	0.5394	0.6693	0.5624	0.0649	0.1806	0.3464	0.1805	$x \rightarrow y$
JAPAN	1950–90	0.0417	0.0929	0.2176	0.0319	0.6121	0.7284	0.8070	0.7468	$y \rightarrow x$
JORDAN	1954–90	0.2271	0.4240	0.5763	0.4326	0.4162	0.5558	0.6693	0.5926	
REP. OF KOREA	1953–89	0.2134	0.3296	0.4518	0.2737	0.5205	0.6209	0.6980	0.6439	$y \rightarrow x$
KUWAIT	1985–89	NA	NA	NA	NA	NA	NA	NA	NA	NA
LAOS	1984–90	NA	NA	NA	NA	NA	NA	NA	NA	NA
MALAYSIA	1955–90	0.4703	0.6033	0.7176	0.6081	0.3922	0.5324	0.6278	0.5308	
MONGOLIA	1984–90	NA	NA	NA	NA	NA	NA	NA	NA	NA
MYANMAR	1950–89	0.3091	0.4030	0.5150	0.3824	0.1000	0.2262	0.4186	0.2272	
NEPAL	1951–86	0.7522	0.8168	0.8619	0.8267	0.1376	0.2434	0.4133	0.2107	$x \rightarrow y$
OMAN	1985–89	NA	NA	NA	NA	NA	NA	NA	NA	NA
PAKISTAN	1950–90	0.1419	0.2614	0.3814	0.2381	0.2593	0.3934	0.5234	0.3966	$(y \rightarrow x)$
PHILIPPINES	1950–90	0.3630	0.4364	0.4961	0.4494	0.3266	0.3815	0.4474	0.3689	
QATAR	1985–89	NA	NA	NA	NA	NA	NA	NA	NA	NA
SAUDI ARABIA	1985–89	NA	NA	NA	NA	NA	NA	NA	NA	NA
SINGAPORE	1960–90	0.3802	0.5784	0.7207	0.5638	0.1837	0.3589	0.5122	0.3877	
SRI LANKA	1950–89	0.3573	0.5201	0.6551	0.4761	0.2513	0.4328	0.6093	0.4235	
SYRIA	1960–90	0.4872	0.6182	0.7135	0.6486	0.1692	0.2880	0.3897	0.2672	$x \rightarrow y$
TAIWAN	1951–90	0.5104	0.6487	0.7380	0.6546	0.2030	0.3535	0.4686	0.3838	$x \rightarrow y$
THAILAND	1950–90	0.2187	0.3367	0.4457	0.2948	0.1945	0.2852	0.4250	0.2440	
UNITED ARAB EMIRATES	1985–89	NA	NA	NA	NA	NA	NA	NA	NA	NA
YEMEN	1969–89	0.0426	0.1303	0.3005	0.0952	0.4047	0.5773	0.6827	0.6081	$y \rightarrow x$
AUSTRIA	1950–90	0.2499	0.3868	0.5659	0.3143	0.2721	0.3442	0.4105	0.3490	
BELGIUM	1950–90	0.3543	0.5215	0.6470	0.5131	0.1526	0.2371	0.3686	0.2289	$(x \rightarrow y)$
BULGARIA	1980–90	NA	NA	NA	NA	NA	NA	NA	NA	NA
CYPRUS	1950–90	0.4553	0.5452	0.6235	0.5504	0.3237	0.4437	0.5650	0.4327	
CZECHOSLOVAKIA	1960–90	0.1164	0.2343	0.3975	0.1980	0.2796	0.3990	0.5318	0.4199	$(y \rightarrow x)$
DENMARK	1950–90	0.2949	0.4708	0.6292	0.4911	0.2968	0.4123	0.6020	0.4894	
FINLAND	1950–90	0.3737	0.4506	0.5457	0.4357	0.3863	0.5268	0.6378	0.5408	
FRANCE	1950–90	0.1232	0.2602	0.4301	0.2368	0.2889	0.3768	0.4831	0.3589	

Table 9. Continued

FED. REP. GERMANY	1950–90	0.0413	0.1052	0.2170	0.0512	0.0671	0.1468	0.2525	0.1340	
GREECE	1950–90	0.2552	0.4187	0.5750	0.4560	0.3727	0.4785	0.5758	0.4918	
HUNGARY	1970–90	0.4804	0.7365	0.8747	0.7958	0.7758	0.8459	0.9023	0.8463	
ICELAND	1950–90	0.5593	0.6551	0.7300	0.6594	0.1601	0.2418	0.3441	0.2368	$x \to y$
IRELAND	1950–90	0.0304	0.0933	0.2132	0.0383	0.1102	0.2224	0.3817	0.1980	
ITALY	1950–90	0.2794	0.3446	0.4343	0.3451	0.0261	0.1192	0.2806	0.0575	$(x \to y)$
LUXEMBOURG	1950–90	0.0458	0.1012	0.2490	0.0463	0.0865	0.1686	0.2877	0.1421	
MALTA	1954–89	0.7142	0.7724	0.8149	0.7720	0.2938	0.4452	0.5775	0.4587	$x \to y$
NETHERLANDS	1950–90	0.2272	0.4475	0.6190	0.4218	0.1794	0.2504	0.3277	0.2447	
NORWAY	1950–90	0.2387	0.3720	0.5059	0.3156	0.3919	0.5142	0.6241	0.4843	
POLAND	1970–90	NA	NA	NA	NA	NA	NA	NA	NA	NA
PORTUGAL	1950–90	0.1646	0.3163	0.4727	0.3082	0.3795	0.5128	0.6195	0.5312	$(y \to x)$
ROMANIA	1985–85	NA	NA	NA	NA	NA	NA	NA	NA	NA
SPAIN	1950–90	0.1211	0.2571	0.3994	0.2206	0.1763	0.2853	0.4243	0.2699	
SWEDEN	1950–90	0.4790	0.5776	0.6613	0.5687	0.5153	0.6613	0.7780	0.6983	
SWITZERLAND	1950–90	0.2759	0.4054	0.5356	0.4002	0.0562	0.1170	0.2090	0.0971	$x \to y$
TURKEY	1950–90	0.0937	0.2327	0.4390	0.2749	0.0927	0.2388	0.4039	0.2222	
U.K.	1950–90	0.1149	0.2008	0.3295	0.1472	0.1918	0.3245	0.4774	0.3313	$(y \to x)$

[a] $F_{x \to y|m}$ is the measure of linear feedback from exports to income, conditional on imports. $F_{y \to x|m}$ is interpreted similarly. Table entries are the point estimate (pt. est.) and the 1st, 5th, and 9th deciles of the posterior distributions of $1 - \exp(-F_{x \to y|m})$. This latter quantity is analogous to the coefficient of determination (R^2) or fraction of variation explained.

[b] $x \to y$ means that the 10th posterior decile of $1 - \exp(-F_{x \to y|m})$ lies above the 90th posterior decile of $1 - \exp(-F_{y \to x|m})$. $(x \to y)$ means that the point estimate of $1 - \exp(-F_{x \to y|m})$ lies above the 90th posterior decile of $1 - \exp(-F_{y \to x|m})$, and the point estimate of $1 - \exp(-F_{y \to x|m})$ lies below the 10th posterior decile of $1 - \exp(-F_{x \to y|m})$. $y \to x$ and $(y \to x)$ are interpreted similarly.

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First version received: January 1995
Final version received: November 1995