

THE EXPORT-LED GROWTH HYPOTHESIS REVISITED: THEORY AND EVIDENCE*

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ABSTRACT

Export growth is often singled out as a key aspect in processes of fast and sustainable increases in per capita income. In this paper we revisit this export-led growth hypothesis (ELGH). From an empirical point of view we study this phenomenon applying Granger-type tests on panel data. The results seem to confirm that, for the sample of countries and the period under study, exports did behave as the "engine of growth" as they Granger-caused investment, output growth and imports. In the theoretical part of the paper we reframe the ELGH standard model in terms of recent models of endogenous growth so as to make it more consistent with these empirical findings.

SINTESIS

Con frecuencia el crecimiento de las exportaciones se identifica como un aspecto clave en los procesos de aumentos rápidos y sostenidos del ingreso per cápita. En este trabajo reexaminamos la hipótesis del crecimiento liderada por las exportaciones (HCLE). Desde un punto de vista empírico se estudia este fenómeno aplicando pruebas del tipo Granger a datos de panel. Los resultados parecen confirmar que, para la muestra de países y el período estudiado, las exportaciones actuaron como el "motor de crecimiento" ya que tuvieron esa causalidad de Granger sobre la inversión, el crecimiento de la producción y las exportaciones. En la parte teórica del trabajo, se reformula el modelo tradicional de la HCLE en términos de modelos recientes de crecimiento endógeno para hacerla más consistente con estos hallazgos empíricos.

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1. INTRODUCTION

Since the mid-80s several Latin American countries have undertaken major economic reforms. Among the many measures that were taken, trade liberalization occupied a central place, breaking a long tradition (almost four decades) of import substitution policies in the region. One of the main reasons for the change in attitude was probably the view that economic openness contributes to growth¹. In this regard, it is widely agreed that import substitution policies did not help to close the income gap between the countries of the region and the developed world. On the contrary, on average, growth in Latin America has been erratic and modest.

This evidence sharply contrasts with that of East Asian countries. As it is well documented², the outward-oriented trade policies followed by those nations have been associated with an impressive growth in exports and in GDP. Thus, for many observers, export growth has become a key feature of an overall strategy to obtain a rapid and sustainable increase in per capita income. The move toward liberalization in Latin America could then be understood as a way of adopting an "Asian-type", export-led, growth pattern³.

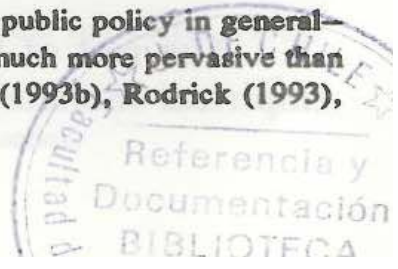
But, what are the reasons for exports to have a role (independent of factor accumulation)) in this process? Moreover, beyond the case of four or five Asian

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¹ For a detailed discussion of economic reform in Latin America see Rodrick (1993) and Banco Mundial (1993a).

² See, for example, Banco Mundial (1993b) and Thomas and Wang (1993).

³ There has been a long and still ongoing controversy regarding trade policy –and public policy in general– in East Asia. The key issue is that government intervention in those countries is much more pervasive than what people initially thought. On this issue see Edwards (1993), Banco Mundial (1993b), Rodrick (1993), King and Leipzig (1993).



countries, how strong, widespread and robust is the evidence that shows a positive, long term relationship between exports and growth in GDP? And, even if we identify such a positive relationship, how can we be sure that a strong GDP growth is a consequence of an increase in exports and not the other way round?

The purpose of the paper is to address these questions both from an empirical and a theoretical perspective. From an empirical view, there are many studies based on cross-section data which include trade indicators but few of them take care of the "robustness" of their results. Moreover, regressing one variable on others says nothing about the exogeneity of the regressors, although this is a critical question to understand which factors sustain growth. The literature that controls for robustness suggests that trade –broadly defined–, investment and output growth are positively related. Notwithstanding, the issue of "exogeneity" is left open. With the purpose of clarifying this last issue we perform Granger causality tests applied to panel data. The analysis is developed distinguishing exports from imports behavior. Panel data estimation allows to study the time series relationship between trade and growth for a wide range of countries. This approach permits to evaluate the "exogenous" role of exports, as far as Granger causality is concerned. The result of this empirical analysis shows that for the sample considered (which includes a set of developed and developing countries from the 70's to the early 90's) exports appear as Granger causing both investment and per capita output. Instead, this result is not found when trade is measured using imports.

Can these "facts" be understood with the available theoretical models?. A pioneer work in this field is Feder (1982) which can be considered as the "classic" export-led growth model (ELGM). In this model the role of exports as the "engine" of growth is based on the assumptions of "cross-sector externalities" plus a "productivity differential". Nevertheless, as it is shown below, there are some difficulties with this formulation to explain a long term relationship between exports and growth. We reframe the ELGM in terms of the modern theory of endogenous growth. This reformulation allows a better understanding of the role that externalities and productivity differentials play in economic growth. Contrary to what is derived from the simple ELGM analysis, the existence of positive externalities is neither a necessary nor a sufficient condition for exports to have a positive, lasting effect on capital accumulation. Similar to Lucas' (1988) analysis for the case of human capital, in our model a key condition to obtain sustained growth is that productivity of capital in the exportable sector is not subject to diminishing returns, while in the nontradable sector the marginal productivity of capital is decreasing. Still, this condition can be understood as the "productivity differential" (between the exportable and non-exportable sectors) proposition which appears as an argument in the ELGM literature.

The rest of the paper is organized as follows. Section 2 revises previous empirical literature on the subject and presents the Granger causality tests using

panel data. Section 3 discusses the standard ELMG model. In section 4 we rewrite this model in terms of the endogenous growth theory. Finally, section 5 concludes.

2. EMPIRICAL ANALYSIS: CAUSALITY TESTS IN PANEL DATA

In recent years there has been an explosion of empirical studies that try to assess the determinants of the long term pattern of growth in per capita income⁴. In most cases these studies perform cross country regressions where the average rate of growth in per capita income is regressed on investment and other variables. Many of these regressions include foreign trade indicators as explanatory variables. Two recent papers, Levine and Renelt (1991) (1992) try to assess the robustness of these cross-country empirical analyses. Following the "Specification Searches" methodology developed by Leamer (1978), they run a sensitivity analysis in order to identify which correlations are maintained when the list of regressors is modified⁵. They show that many results are not robust. However, directly related to the issue of growth and exports, they found the following: (i) a positive and robust correlation between average growth rate of per capita income and investment-output ratio; (ii) a positive and robust correlation between investment-output ratio and the ratio of exports, imports or total trade to GDP.

The empirical evidence then suggests that trade (i.e., exports and imports), investment and growth in GDP per capita are robustly related. Nevertheless, such a positive correlation says nothing about the nature of these relationships. Different authors have suggested different directions in which these variables interact with each other. Feder (1982) postulates an effect that goes from exports to GDP. On the other hand, Esfahani (1991) and Lee (1993) suggest that total imports is the variable that takes the leading role in affecting exports and GDP performance. Furthermore, increases in exports and imports can be a consequence of GDP growth.

To clarify these questions we empirically analyze the relationship between exports, imports, investment and growth applying "Granger-Causality Tests" to a pooling of (cross section- time series) data⁶. The approach followed is similar to that applied by Carroll and Weil (1994) to study the relationship between growth and savings. It should be emphasized that this kind of analysis is not aimed at finding "structural" relationships. At most, it allows detecting "time-

⁴ See for example the papers of Barro (1991), Mankiw et al (1992), Feliz (1992), Gould and Ruffin (1993), Edwards (1992), Roubini and Sala-i-Martin (1991).

⁵ See also Fuentes (1992).

⁶ See Harvey (1981) for definitions and methodology of Granger Causality for time series.

anticipations" of a variable⁷. A well-known limitation of the methodology is that when causality is analyzed between two variables- a third one may be "causing" both. Granger causality holds in this context when the past of a variable (say X_{t-1}) helps to predict the other variable (say Y_t) in addition to its own past (Y_{t-1}); then X Granger-causes Y . (The analysis may be symmetrically applied for X on Y).

Similarly to Carroll and Weil, we transformed the original data set into non-overlapping four-year averages computed for a sample of 27 developed and less-developed countries during the 1971-1991 period⁸. These averages allow to isolate long-run effects from short-term (cyclical) movements. Both OLS and instrumental variables estimations (IVE) were performed (see appendix for details). The variables were defined as differences (of logs) assuming that fixed (countries) effects were given only in the levels of such variables. Dummy variables were also included for time-specific effects. Then (bivariate) causality was analyzed for dy_t , dx_t , dm_t and di_t , which denote the (average) growth of per capita GDP, exports, imports and fixed investment, respectively, all in constant prices. All the data was taken from World Bank's World Tables. Results are presented in tables 1 to 8.

It is clear that, for the sample analyzed, the previous behavior of exports (measured as four-year averages of log differences) has been positively related to that of growth. This result stands whether estimation is done using OLS or IVE (see table 1a and 2a). Such anticipation of export variations also appears in the case of investment and imports (tables 3a and 5a for OLS and 4a and 6a for IVE). Thus, exports are leading the growth process (anticipate GDP growth and investment) and, given that in the long run we should have balanced trade, exports anticipate imports.

The reverse direction of causality between these variables (see table 7 and 8) is more difficult to assess for this information set due to either non-significant "t" statistics, residual autocorrelation or heteroscedasticity at traditional significance levels. Only some feedback of investment to exports may be found (see table 7b), but some evidence on heteroscedasticity is present.

Another critical result for this sample, is that imports, quite different from exports, have no positive effect either on GDP or on investment (see table 1b and 3b for OLS estimation and 2b and 4b for IVE estimation). Therefore, in terms of its growth effect, it makes a difference how "trade" is defined.

⁷ It should be noted that Granger Non-causality is neither necessary nor sufficient for "weak exogeneity" as defined by Engle et al. (1983). (Both weak and Granger non-causality are necessary for "strong exogeneity").

⁸ Carroll and Weil use five-year averages and their sample contains 22 countries. Our 27-country sample contains Argentina, Algeria, Australia, Bolivia, Brazil, Canada, Chile, Cote d' Ivoire, Colombia, Costa Rica, Germany, Spain, France, India, Israel, Italy, Japan, Korea, Sri Lanka, Mexico, Malaysia, Netherlands, Sweden, Thailand, Tunisia, Uruguay and USA.

In addition we found that GDP growth would anticipate that of investment (though some degree of heteroscedasticity is also observed here; see table 3c (OLS) and table 4c (IVE)), whereas the reverse direction cannot be proved for this sample (see table 1c and 2c)). This is a result in line with the analysis of King and Levine (1994) and similar to that of Carroll and Weil (1994) for the case of saving.

In summary the results obtained from performing Granger causality test to panel data indicate that exports, and not imports, lead the growth process since they anticipate the behavior of both investment and per capita GDP. In the next sections we discuss and reframe the export-led theoretical literature so as to make it consistent with this evidence.

3. EXPORTS AND GDP GROWTH: THE STANDARD EXPORT-LED GROWTH MODEL

The idea that foreign trade and, in particular, exports have growth implications has often been emphasized in the development literature⁹. Factors like externalities, economies of scale, technological improvement, learning, etc. have been mentioned as being encouraged by trade liberalization and by the increase in the exchange of goods and services in the world markets.

Nevertheless, it was not until Feders' work (see Feder (1982)) that some of those intuitive ideas were put into a formal setup, constituting what we call the export-led growth model (ELGM). In this model, exports have a positive effect on GDP growth due to the following two reasons. First, the exportable sector generates positive externalities on the other sectors of the economy through technological spill-overs and also through the transmission of new management techniques. Second, it is assumed that factor productivity is higher in the exportable sector compared to the non-exportable. Thus any trade liberalization policies that induce a reallocation of factors of production into exportables, and out of the other sectors of the economy, will have a positive effect on aggregate GDP.

More formally, the model assumes that the economy is divided into two sectors: exportables (X) and nontradables (N). The production functions have the usual neoclassical properties,

$$N = F(K_N, L_N, X) \quad (1)$$

⁹ For early work on the relationship between trade policies, foreign trade and growth see Little et al. (1970), Balassa (1971), Krueger (1978) y Bhagwati (1978).

$$X = G(K_X, L_X) \quad (2)$$

where K_i, L_i , with $i = X, N$, denote the quantity of capital and labor used in each sector. The inclusion of the exportable output into the nontradable production function (where $F_X > 0$) captures the externality effect mentioned above. On the other hand, the assumption of a factor productivity differential is represented by the following condition,

$$\frac{G_K}{F_K} = \frac{G_L}{F_L} = 1 + \gamma \quad (3)$$

where G_K, F_K denote the marginal productivities of capital in each sector, respectively, and G_L, F_L do the same for the case of labor. The positive constant γ indicates to what extent factor productivities in the exportable sector are higher compared to the non tradable sector. This may reflect a disequilibrium situation where static gains can be achieved by reallocating resources from one activity to the other or, alternatively, the existence of taxes or other intersectoral distortions that negatively affect exportable goods. Total output is only the sum of production in both activities¹⁰,

$$Y = X + N \quad (4)$$

Differentiating (4) and using (1)-(3), the following expression representing aggregate GDP growth is obtained,

$$\frac{\dot{Y}}{Y} = \alpha \frac{\dot{I}}{Y} + \beta \frac{\dot{L}}{L} + [F_X + \frac{\gamma}{1+\gamma}] \frac{X}{Y} \frac{\dot{X}}{X}$$

where I/Y is the investment-output ratio, \dot{L}/L the growth rate of employment and X/Y the export-output ratio¹¹. The presence of the growth rate of exports in expression (5) distinguishes this model from the standard growth accounting equation. Thus, due to intersectoral spillovers and productivity differentials, exports appear as an independent factor that pushes the rate of growth of output beyond what is determined by the accumulation of capital and labor.

¹⁰ The assumption of unit relative prices has been relaxed in an improved version of the Feder model developed by Bilginsoy and Khan (1994).

¹¹ The α and β coefficients should be interpreted as indicative of the marginal product of capital and labor in the non-tradable sector, not those in the economy as a whole. See Feder (1982) for details.

Equation (5) has been profusely used in empirical work¹². Nevertheless, from a theoretical point of view, there are some limitations which undermine its ability to provide a justification for a long-run relationship between exports and GDP growth. First, even if we initially assume a disequilibrium state where marginal productivities are not equalized across sectors, it is difficult to see why such a differential will not be reduced, and eventually eliminated, as exports increase. Once we allow for the overall level of investment and population growth, the increase in exports is signaling a reallocation of resources towards the exportable sector. But of course this reallocation will reduce the marginal productivity of factors in that sector making the productivity differential smaller. And, at some point, the differential will vanish.

Second, if, instead, the initial situation is one of equilibrium, where the productivity differential is due to taxes and other inter-sectoral distortions, there will be no reallocation of production factors. So exports, as production of nontradable goods, will expand at the rate that factor accumulation dictates, having no independent role in economic growth. We conclude then that productivity differentials imply only a static welfare gain that, within the context of the model, would not have any growth effect.

With respect to the cross-sector externality, we would arrive at the same conclusion as before if the elasticity of non tradable output with respect to exports ($F_X X/(Y-X)$) declines with X . The positive effect of exports on GDP growth will decline as this elasticity gets smaller and smaller as the export share increases¹³. On the other hand, if a constant elasticity of nontradable output with respect to exports is assumed —as in Feder (1982)— then the intersectoral externality may have growth consequences even in the long-run. But, then, the question is, why exports will continue to grow in the first place. Why will investment and output in the exportable sector keep rising if capital is subject to diminishing marginal returns? Of course, these questions are beyond the scope of the original ELGM literature as these studies take exports growth as exogenous. Nevertheless, these questions have to be addressed if we want to understand under what circumstances exports can perform as the "engine" of economic growth. But to do this we need to reframe the ELGM in terms of an explicit growth theory. This is done in the next section.

3. EXPORTS AND GROWTH: AN ENDOGENOUS GROWTH MODEL

The formalization of the relationship between trade liberalization, exports (and imports) and growth has not been easy even within the context of explicit

¹² Beyond Feder (1982) several authors have estimated equation (5) or slight variations of it. See for example Moschos (1989), Esfahani (1991), Dollar (1992) and Bilginsoy and Khan (1994).

¹³ Bilginsoy and Khan (1994) extended the original Feder model incorporating variable (diminishing) elasticity.

models of economic growth. The traditional neoclassical growth model (Solow (1956), Koopman (1965)) predicts that, in the long run, these policies have only level effects. Sustainable increases in per capita income is then only possible by the exogenous improvement in technology¹⁴.

The theory of endogenous growth came out in part as a solution to this problem (see Lucas (1988), Romer (1986), Rebelo (1991)). With a slight modification in the traditional neoclassical production function, these models can successfully obtain equilibria where per-capita income grows continuously without requiring an exogenous increase in total factor productivity. The key assumption is to postulate a lower bound (greater than zero) for the value of the marginal productivity of physical (human) capital¹⁵. With this purpose we assume a production technology where output is a function of an aggregate measure of capital (human and physical) times a constant (the Ak-Rebelo specification)¹⁶.

The model

In what follows we study the relationship between trade policies, exports, imports and economic growth in the context of a Rebelo-type, endogenous-growth model. We consider the case of an open economy with three sectors: exportable, importable and nontradable. To simplify the analysis we assume that residents of this economy consume only the exportable and the nontradable goods, while the importable good is an input of production (capital). Also, locally, only the exportable and the nontradable goods are produced. All the importable goods (capital) are then imported. The production functions corresponding to the nontradable (N) and exportable (X) sectors are given by the following expressions,

$$Q_N = AK_N^\alpha L_N^{1-\alpha} Q_X^\eta \quad (6)$$

$$Q_X = BK_X \quad (7)$$

where Q_i , $i = X, N$ denotes the quantity produced of each good. We assume nontradables are produced using a constant return to scale technology that employs both capital (K_N) and (raw) labor (L_N). In addition, as in the ELGM

¹⁴ This does not preclude that trade policies, and public policies in general, can have growth effects in the transitional period, before reaching the steady state. This avenue of research has been explored by some authors with some success (see, for example, Barro (1991), Lee J. (1993), Mankiw et al. (1992), Gould and Ruffin (1993)).

¹⁵ It should be mentioned that there is another branch of the endogenous growth literature that also obtains equilibria with sustained growth but, in this case, the emphasis is placed on the "endogenous" process of technological development (see Romer (1990), Grossman and Helpman (1991) (1993)).

¹⁶ A lower positive bound for the marginal productivity of capital is also obtained with a CES specification.

model, the exportable sector generates a positive externality on the production of nontradable (Q_X is included as an argument in Q_N). Again, this assumption captures the existence of technology spill-overs as well as the transmission of managerial skills, training etc. Exportable output is produced with a technology that uses only capital (K_X) which is not subject to diminishing marginal returns; the marginal product of capital in that sector is constant and equal to B^{17} . Instead, the production of nontradable goods is subject to diminishing returns, especially when the marginal productivity of capital is evaluated from a decentralized point of view.

As indicated above, this specification of the production functions constitutes a key assumption assuring the existence of an equilibrium with a positive, steady-state growth rate of per capita output. At the same time, it is a way of "recreating" the productivity differential assumption of the early ELGM literature. For simplicity we assume total population L stays constant and we normalize it to one.

Consumers in this economy have time separable preferences, represented by the following intertemporal utility function,

$$\int_0^{\infty} \frac{e^{\rho t} (c_X^\theta c_N^{1-\theta})^{1-\gamma}}{1-\gamma} dt \quad (8)$$

¹⁷ Rebelo himself (see Rebelo (1991) and Barro and Sala-i-Martin (1995)) have shown that this production function can be derived from a more general one where output depends both on physical and human capital. Suppose, for example, that instead of equation (7), the production of exportables is determined by the following expression,

$$Q_X = BK_X^\theta H_X^{(1-\theta)} \quad (a.1)$$

where H_X denotes the amount of human capital used in the production of exportables. Rearranging,

$$Q_X = BK_X \left(\frac{H_X}{K_X}\right)^{(1-\theta)} \quad (a.2)$$

In equilibrium the marginal productivities (net of depreciation) of human and physical capital will be equal. This gives a constant value for the ratio H_X/K_X . Thus, (a.2) can be rewritten as,

$$Q_X = B'K_X ; \quad B' = B \left(\frac{H_X}{K_X}\right)^{(1-\theta)} \quad (a.3)$$

Then the non-diminishing return assumption in the exportable sector can be understood as a consequence of physical and human capital being used in the production of this good. And, as the two factors can be accumulated, the marginal productivity of physical capital does not decline as output rises.

where c_X and c_N denote consumption of exportable and nontradable goods. We assume all markets are always in equilibria. Then,

$$Q_X = C_X + X \quad (9)$$

$$Q_N = C_N \quad (10)$$

where X indicates total exports. As we are interested in the steady state solution—where countries cannot accumulate positive (or negative) debt—, we postulate that the trade account is in balance period after period,

$$M = p_X X \quad (11)$$

where M represents total imports and p_X indicates the relative price of exports in terms of imports (the terms of trade) which, given the assumption of a small open economy, is constant. In this economy the accumulation of aggregate capital ($K = K_X + K_N$) is determined by the volume of imports ($M = \dot{K}$). But, given the balanced trade assumption, this is, in turn, equal to total exports. Using equations (9) and (11), the expression that describes the law of motion of capital is then equal to,

$$\dot{K} = p_X (B (K - K_N) - C_X) \quad (12)$$

We solve the model assuming home-production (we do not deal explicitly with the behavior of firms and factor markets). The present value Hamiltonian that summarizes the dynamic problem faced by the representative family is,

G1

$$H(.) = e^{-\rho t} \frac{(c_X^\theta c_N^{1-\theta})^{1-\gamma}}{1-\gamma} + \lambda [p_X (B (K - K_N) - c_X)] + \phi [AK_N^\alpha Q_X^\eta - c_N] \quad (13)$$

where λ is the standard dynamic multiplier indicating the shadow price of a unit exportable good. ϕ is the multiplier corresponding to the nontradable market equilibrium condition. It is the equilibrium price of nontradable in terms of importable (in present value terms) taken as given by the representative family. For the decentralized case, where C_X, C_N and K_N are controls and K is a state variable, the first-order conditions are,

$$e^{-\rho t} (C_X^\theta C_N^{1-\theta})^{-\gamma} \theta C_X^{\theta-1} C_N^{1-\theta} = \lambda p_X \quad (14)$$

$$\frac{\theta}{1-\theta} \frac{c_N}{c_X} = \frac{\lambda p_X}{\phi} \quad (15)$$

$$\frac{\lambda p_X}{\phi} = \frac{A\alpha K_N^{\alpha-1} Q_X^\eta}{B} \quad (16)$$

$$p_X B = - \frac{\dot{\lambda}}{\lambda} \quad (17)$$

Equation (14) shows that the shadow price of the exportable good equals the present value of the marginal utility of consumption with respect to exportables. In turn condition (15) indicates that an optimal allocation of consumption between the two goods within a given period should satisfy the standard condition that the ratio of marginal utilities be equal to the ratio of prices. Expression (16) establishes the condition for intratemporal efficiency in production: the ratio of prices has to be equal to the marginal rate of transformation. Finally, equation (17) indicates that to be in an intertemporal equilibrium, consumption should rise at a rate such that the marginal utility of consumption with respect to the tradable good declines at a rate equal to the marginal productivity of capital in the exportable sector.

We are going to solve the above system for the steady state case. A closed form solution for the indicated system is easy to obtain for the case where the rates of growth in both sectors are related by the following expression $g_N = g_X (\alpha + \eta)$. Below we show that this conjecture is consistent with the first-order conditions (14)-(17) and we derive an explicit formula for g_X .

Making (15) and (16) equal, applying natural log and differentiating we arrive at,

$$\frac{\dot{c}_N}{c_N} = g_{c_N} = g_{c_X} + (\alpha - 1) \frac{\dot{K}_N}{K_N} + \eta \frac{\dot{K}_X}{K_X} \quad (18)$$

On the other hand, if $g_X = g_N (\alpha + \eta)$ using the expression for the production functions (6) and (7) it is easy to show that $\dot{K}_X/K_X = \dot{K}_N/K_N$. From this result, together with equation (12) and the fact that $K = K_X + K_N$, it follows that in this equilibrium $g_X = g_{c_X}$.

Replacing all of these derivations into expression (18) we get $g_{c_N} = g_X (\alpha + \eta)$ which, of course, makes the steady state growth in consumption of nontradable consistent with the postulated growth in nontradable output.

Applying a logarithmic transformation to expression (14) and differentiating with respect to time we arrive at the following equation,

$$-\rho - g_X \{ \gamma(\theta + (1 - \theta)(\alpha + \eta)) + ((1 - \theta) - (1 - \theta)(\alpha + \eta)) \} = \frac{\dot{\lambda}}{\lambda} \quad (19)$$

Which together with condition (17) gives the following explicit expression for the rate of growth of exportable output,

$$g_X = \frac{P_X B - \rho}{h} \quad (20)$$

with

$$h = \gamma (\theta + (1 - \theta)(\alpha + \eta)) + ((1 - \theta) - (1 - \theta)(\alpha + \eta))$$

Using expression (20) we can consider two special cases depending on the value of the parameters involved.

Balanced growth

In this case we assume that the externality effect is big enough so that $\alpha + \eta = 1$. Then, the explicit expression for the common growth rate is,

$$g_X = \frac{P_X B - \rho}{\gamma} \quad (21)$$

This result resembles that found in one sector, Rebelo-type models where the steady state rate of growth of the economy equals the (constant) marginal productivity of capital minus the rate of time preference, both terms multiplied by the elasticity of substitution ($1/\gamma$ in our case)¹⁸.

¹⁸ It is easy to extend the model for the case where imports are charged with an import tax. Assuming T is the tariff, equation (11) can be rewritten as,

$$M(1+T) = p_X X$$

Solving the model as we did before and assuming the special case where $\alpha + \eta = 1$, we arrive at,

$$g_X = g_N = g = \frac{P_X}{(1+T)} \frac{B - \rho}{\gamma}$$

Unbalanced growth

Suppose now that the externality effect is very weak, in the limit, assume that it is zero ($\eta = 0$). The growth rate of nontradable output will be lower than the one observed in the exportable sector (recall that $g_N = g_X (\alpha + \eta)$) which is equal to,

$$g_X = \frac{P_X B - \rho}{\gamma (\theta + (1 - \theta) \alpha) + (1 - \theta) (1 - \alpha)} \quad (22)$$

Still, of course, the model displays sustained growth. In addition, notice that whenever $\alpha + \eta < 1$, there will be also a long-term secular fall in the relative price of exportable goods in terms of nontradable; that is, an equilibrium real exchange appreciation¹⁹.

Within the context of this model it is clear that exports are the "engine" of economic growth. This sector sustains the continuing increase in per capita income through two channels. On one hand, there is the key assumption that (human and physical) capital in this sector is not subject to diminishing returns. As a consequence, incentives to save do not vanish and so capital accumulation continues for ever; in other words, exports sustain investment and, as capital goods are imported, they also lead to higher import demand.

Secondly, the exportable sector generates positive externalities on the rest of the economy. Though this factor is not a necessary (nor a sufficient) condition to have sustained growth (as in Lucas (1988)), it helps to push upward the growth rate of nontradable output, thus, making balanced growth possible.

5. CONCLUDING REMARKS

Trade liberalization has occupied a central place in recent structural reform programs pursued by many developing countries. Governments hope that, as it happened in East Asia, this policy will encourage export performance and GDP

where $dg/dT < 0$ and $dg/dp_X > 0$. The intuition of these results is clear. An increase in T or a decline in P_X makes importable goods (capital) more expensive in term of exportable products. Then a given amount of exports implies less imports and, then, less capital accumulation in the steady state.

¹⁹ Differentiating equation (16) we find,

$$\frac{\dot{\phi}}{\phi} = \frac{\dot{\lambda}}{\lambda} + (1 - (\alpha + \eta))g_X$$

Thus if $\alpha + \eta < 1$ the price of nontradable goods ϕ grows at a higher rate than the price of exportable λp_X , where both prices are expressed in present-value terms.

growth. In this paper we review this export-led growth hypothesis both from an empirical and a theoretical perspective.

From the empirical point of view, we discuss the literature which shows a robust relationship between trade, growth and investment. Then we try to empirically study the interaction between these variables by performing Granger causality test to panel data. The results indicate that exports, and not imports, Granger-cause growth of both, per capita GDP and investment. Moreover exports cause import flows. Then the evidence suggests that, for the sample of countries chosen and the period considered, exports behave as the "engine of growth".

On the theoretical side, we reframe the traditional export-led growth model (ELGM) (Feder (1982)) in terms of the modern theory of endogenous growth. This makes the theory more consistent with the evidence described. In addition, it helps to overcome some difficulties that the original ELGM approach has in order to provide a theoretical rationale for a long-term, positive association between exports and growth in per capita income. In particular, the existence of non-diminishing returns --as opposed to a productivity differential-- in the exportable sector is a sufficient condition for exports to have a positive, long-term effect on the growth rate of the economy.

TABLE 1

**GRANGER CAUSALITY TEST: dy_t
OLS
(108 observations)**

a) $dx_{t-1} \rightarrow dy_t$

	dy_{t-1}	dx_{t-1}	time effects			
Estimated coefficient	0.25	0.19	.003	.01	-.02	.01
"t" (absolute value)	(2.48)	(3.3)	(0.6)	(1.67)	(3.91)	(1.75)
$R^2 = .34$ $F(5,101) = 10.59[.00]$ $\sigma = .023$ $DW = 2.1$ $AR(1,101) = 0.62 [.43]$ $N(2) = 1.89$						

b) $dm_{t-1} \rightarrow dy_t$

	dy_{t-1}	dm_{t-1}	time effects			
Estimated coefficient	0.47	-.052	.01	.01	-.02	-.01
"t" (absolute value)	(3.46)	(.93)	(2.4)	(1.49)	(3.2)	(1.2)
$R^2 = .28$ $F(5,102) = 7.84[.00]$ $\sigma = .024$ $DW = 2.1$ $AR(1,101) = 1.21[.27]$ $N(2) = 1.74$						

c) $di_{t-1} \rightarrow dy_t$

	dy_{t-1}	di_{t-1}	time effects			
Estimated coefficient	0.50	-0.06	.01	.01	-.02	.01
"t" (absolute value)	(3.3)	(1.04)	(1.9)	(1.6)	(3.1)	(1.4)
$R^2 = .28$ $F(5,102) = 7.90[.00]$ $\sigma = .024$ $DW = 2.1$ $AR(1,101) = 1.57[.21]$ $N(2) = 1.46$						

The symbols dy, dx, dm, di stand for first log-differences in per capita GDP, exports, imports and gross fixed investment. The sub-index t indicates non-overlapping 4-year-averages for the corresponding variables and $t-1$ the same average for the previous four years. The sample includes 27 countries and the time period goes from 1971 to 1991 (4 non-overlapping averages were computed). The numbers under the time effects columns are the estimated coefficients for the constant and dummy variables corresponding to the 1st, 2nd and 3rd time observations. The estimation method is OLS. F stands for the F (joint significance) test and σ denotes the standard error of regression. $AR(1, \dots)$ is the first order autocorrelation F -statistics (Harvey (1981) and $N()$ is the Jarque-Bera (1980) χ^2 statistics under the normality assumption.

TABLE 2

**GRANGER CAUSALITY TEST: dy_t
IVE
(108 observations)**

a) $dx_{t-1} \rightarrow dy_t$

	dy_{t-1}	dx_{t-1}	time effects			
Estimated coefficient	0.35	0.17	.002	.01	-.02	.01
"t" (absolute value)	(2.74)	(2.78)	(0.43)	(1.57)	(3.98)	(1.94)
$\sigma = .023$ DW = 2.3 AR $\chi^2(1) = 2.46$ N(2) = 1.21 ARCH F(1,100) = 1.22 [0.27] HW F(7,94) = 1.75 [0.11]						

b) $dm_{t-1} \rightarrow dy_t$

	dy_{t-1}	dm_{t-1}	time effects			
Estimated coefficient	0.62	-.095	.01	.01	-.02	-.01
"t" (absolute value)	(3.56)	(0.1)	(2.71)	(1.3)	(3.2)	(1.2)
$\sigma = .024$ DW = 2.3 AR $\chi^2(1) = 3.39$ N(2) = 1.80 ARCH F(1,100) = 0.10 [0.74] HW F(7,94) = 1.79 [0.10]						

c) $di_{t-1} \rightarrow dy_t$

	dy_{t-1}	di_{t-1}	time effects			
Estimated coefficient	0.81	-0.14	.005	.01	-.02	.01
"t" (absolute value)	(3.34)	(1.87)	(0.8)	(1.6)	(2.9)	(1.7)
$\sigma = .023$ DW = 2.4 AR $\chi^2(1) = 5.73$ N(2) = 3.88 ARCH F(1,100) = 0.06 [0.80] HW F(7,94) = 3.43 [0.03]						

The symbols dy, dx, dm, di stand for first log-differences in per capita GDP, exports, imports and gross fixed investment. The sub-index t indicates non-overlapping 4-year-averages for the corresponding variable along the 27-country sample. The time period considered goes between 1971 to 1992 (4 non-overlapping averages were computed). The numbers under the lags column are the estimated coefficients for the constant and dummy variables corresponding to the 1st, 2nd and 3rd lags. The estimation method is Instrumental Variables (IVE). σ denotes the average estimation error. AR $\chi^2(1)$ is the first order autocorrelation statistics (for IVE estimation). N () is the χ^2 Jarque-Bera (1980) statistics under the normality assumption. ARCH (1,.) is the F statistic for conditional autoregressive heteroscedasticity (of 1st order) and HW(.,.) is the White's F statistic for heteroscedasticity due to the square of regressors.

TABLE 3

**GRANGER CAUSALITY TEST: di_t
OLS
(108 observations)**

a) $dx_{t-1} \rightarrow di_t$

	di_{t-1}	dx_{t-1}	time effects			
Estimated coefficient	0.02	0.51	.01	.02	-.08	-.01
"t" (absolute value)	(0.02)	(2.99)	(0.8)	(1.3)	(3.8)	(0.40)
$R^2 = .25$ $F(5,102) = 6.71[.00]$ $\sigma = .071$ $DW = 2.0$ $AR(1,101) = 0.01[.91]$ $N(2) = 3.06$						

b) $dm_{t-1} \rightarrow di_t$

	di_{t-1}	dm_{t-1}	time effects			
Estimated coefficient	0.12	-.03	.04	.01	-.07	-.02
"t" (absolute value)	(0.7)	(.2)	(2.58)	(1.2)	(3.28)	(0.85)
$R^2 = .18$ $F(5,102) = 4.53[.00]$ $\sigma = .07$ $DW = 1.9$ $AR(1,101) = 0.13[.72]$ $N(2) = 4.6$						

c) $dy_{t-1} \rightarrow di_t$

	di_{t-1}	dy_{t-1}	time effects			
Estimated coefficient	-0.26	1.33	.02	.02	-.07	-.01
"t" (absolute value)	(1.6)	(2.85)	(1.7)	(1.2)	(3.3)	(0.32)
$R^2 = .24$ $F(5,102) = 6.51[.00]$ $\sigma = .072$ $DW=2.1$ $AR(1,98) = 0.84[.36]$ $N(2) = 0.91$						

The symbols dy, dx, dm, di stand for first log-differences in per capita GDP, exports, imports and gross fixed investment. The sub-index t indicates non-overlapping 4-year-averages for the corresponding variable along the 27-country sample. The time period considered goes between 1971 to 1992 (4 non-overlapping averages were computed). The numbers under the lags column are the estimated coefficients for the constant and dummy variables corresponding to the 1st, 2nd and 3rd lags. The estimation method is Ordinary Least Squares (OLS). F stands for the F (joint significance) test and σ denotes the average estimation error. $AR(1, \dots)$ is the first order autocorrelation statistics (Harvey (1981)). $N(\dots)$ is the χ^2 Jarque-Bera (1980) statistic under the normality assumption.

TABLE 4

**GRANGER CAUSALITY TEST: di_t
IVE
(108 observations)**

a) $dx_{t-1} \rightarrow di_t$

	di_{t-1}	dx_{t-1}	time effects			
Estimated coefficient	-0.16	0.58	.01	.03	-.07	-.01
"t" (absolute value)	(1.13)	(3.28)	(0.7)	(1.4)	(3.3)	(0.69)
$\sigma = .073$ DW = 1.7 AR $\chi^2(1) = 2.88$ N(2) = 4.58 ARCH F(1,100) = 3.77 [0.06] HW F(7,94) = 1.01 [0.43]						

b) $dm_{t-1} \rightarrow di_t$

	di_{t-1}	dm_{t-1}	time effects			
Estimated coefficient	-0.15	0.22	.03	.03	-.07	-.02
"t" (absolute value)	(0.7)	(0.9)	(2.1)	(1.5)	(3.04)	(0.7)
$\sigma = .076$ DW = 1.8 AR $\chi^2(1) = 2.09$ N(2) = 5.73 ARCH F(1,100) = 1.59 [0.21] HW F(7,94) = 0.94 [0.48]						

c) $dy_{t-1} \rightarrow di_t$

	di_{t-1}	dy_{t-1}	time effects			
Estimated coefficient	-0.59	2.06	.01	.03	-.06	-.01
"t" (absolute value)	(2.3)	(3.2)	(0.7)	(1.4)	(2.7)	(0.3)
$\sigma = .071$ DW = 1.97 AR $\chi^2(1) = 0.02$ N(2) = 0.58 ARCH F(1,100) = 0.97 [0.33] HW F(7,94) = 2.58 [0.02]						

The symbols dy, dx, dm, di stand for first log-differences in per capita GDP, exports, imports and gross fixed investment. The sub-index t indicates non-overlapping 4-year-averages for the corresponding variable along the 27-country sample. The time period considered goes between 1971 to 1992 (4 non-overlapping averages were computed). The numbers under the lags column are the estimated coefficients for the constant and dummy variables corresponding to the 1st, 2nd and 3rd lags. The estimation method is Instrumental Variables (IVE). σ denotes the average estimation error. AR $\chi^2(1)$ is the first order autocorrelation statistics (for IVE estimation). N () is the χ^2 Jarque-Bera (1980) statistics under the normality assumption. ARCH (1,.) is the F statistic for conditional autoregressive heteroscedasticity (of 1st order) and HW(.,.) is the White's F statistic for heteroscedasticity due to the square of regressors.

TABLE 5

**GRANGER CAUSALITY TEST: dm_t
OLS
(108 observations)**

a) $dx_{t-1} \rightarrow dm_t$

	dm_{t-1}	dx_{t-1}	time effects			
Estimated coefficient	-0.13	0.30	.06	.02	-.08	-.02
"t" (absolute value)	(1.3)	(2.18)	(4.0)	(1.2)	(4.7)	(1.1)
$R^2 = .31$ $F(5,102) = 9.06[.00]$ $\sigma = .057$ $DW = 1.8$ $AR(1,101) = 1.84[.18]$ $N(2) = 1.09$						

b) $di_{t-1} \rightarrow dm_t$

	dy_{t-1}	dm_{t-1}	time effects			
Estimated coefficient	-0.14	.06	.07	.02	-.07	-.02
"t" (absolute value)	(0.9)	(.42)	(5.7)	(1.1)	(4.34)	(1.35)
$R^2 = .28$ $F(5,102) = 7.8[.00]$ $\sigma = .058$ $DW = 1.7$ $AR(1,101) = 3.35[0.07]$ $N(2) = 2.58$						

c) $dy_{t-1} \rightarrow dm_t$

	dm_{t-1}	dy_{t-1}	time effects			
Estimated coefficient	-0.20	0.39	.06	.02	-.07	-.02
"t" (absolute value)	(1.44)	(1.20)	(5.42)	(1.0)	(4.36)	(1.24)
$R^2 = .29$ $F(5,102) = 8.14[.00]$ $\sigma = .058$ $DW = 1.8$ $AR(1,101) = 2.2[.14]$ $N(2) = 2.78$						

The symbols dy, dx, dm, di stand for first log-differences in per capita GDP, exports, imports and gross fixed investment. The sub-index t indicates non-overlapping 4-year-averages for the corresponding variable along the 27-country sample. The time period considered goes between 1971 to 1992 (4 non-overlapping averages were computed). The numbers under the lags column are the estimated coefficients for the constant and dummy variables corresponding to the 1st, 2nd and 3rd lags. The estimation method is Ordinary Least Squares (OLS). F stands for the F (joint significance) test and σ denotes the average estimation error. $AR(1, \dots)$ is the first order autocorrelation statistics (Harvey (1981)). $N(\)$ is the χ^2 Jarque-Bera (1980) statistic under the normality assumption.

TABLE 6

**GRANGER CAUSALITY TEST: dm_t
IVE
(108 observaciones)**

a) $dx_{t-1} \rightarrow dm_t$

	dm_{t-1}	dx_{t-1}	time effects			
Estimated coefficient	-0.23	0.32	.06	.02	-.07	-.02
"t" (absolute value)	(1.5)	(2.3)	(4.1)	(1.2)	(4.4)	(1.3)
$\sigma = .057$ DW = 1.7 $AR\chi^2(1) = 2.24$ N(2)=1.2 ARCH F(1,100) = 0.28 [0.60] HW F(7,94) = 1.29 [0.26]						

b) $di_{t-1} \rightarrow dm_t$

	di_{t-1}	dm_{t-1}	time effects			
Estimated coefficient	-0.40	0.23	.08	.01	-.07	-.03
"t" (absolute value)	(0.8)	(.67)	(3.9)	(0.8)	(4.16)	(1.39)
$\sigma = .059$ DW = 1.7 $AR\chi^2(1) = 2.16$ N(2) = 4.9 ARCH F(1,100) = 0.19 [0.67] HW F(7,94) = 1.01 [0.43]						

c) $dy_{t-1} \rightarrow dm_t$

	dm_{t-1}	dy_{t-1}	time effects			
Estimated coefficient	-0.37	.68	.07	.01	-.07	-.02
"t" (absolute value)	(1.26)	(1.26)	(5.36)	(.92)	(3.95)	(1.39)
$\sigma = .059$ DW = 1.71 $AR\chi^2(1) = 1.68$ N(2) = 3.9 ARCH F(1,100) = 0.04 [0.84] HW F(7,94) = 1.05 [0.40]						

The symbols dy, dx, dm, di stand for first log-differences in per capita GDP, exports, imports and gross fixed investment. The sub-index t indicates non-overlapping 4-year-averages for the corresponding variable along the 27-country sample. The time period considered goes between 1971 to 1992 (4 non-overlapping averages were computed). The numbers under the lags column are the estimated coefficients for the constant and dummy variables corresponding to the 1st, 2nd and 3rd lags. The estimation method is Instrumental Variables (IVE). σ denotes the average estimation error. $AR \chi^2(1)$ is the first order autocorrelation statistics (for IVE estimation). $N()$ is the χ^2 Jarque-Bera (1980) statistics under the normality assumption. ARCH (1,.) is the F statistic for conditional autoregressive heteroscedasticity (of 1st order) and HW(.,.) is the White's F statistic for heteroscedasticity due to the square of regressors.

TABLE 7

**GRANGER CAUSALITY TEST: dx_t
OLS
(108 observations)**

a) $dm_{t-1} \rightarrow dx_t$

	dx_{t-1}	dm_{t-1}	time effects			
Estimated coefficient	0.17	0.13	.05	.01	-.04	-.002
"t" (absolute value)	(1.78)	(1.84)	(5.5)	(.78)	(3.9)	(0.02)
$R^2 = .21$ $F(5,102) = 5.5[.00]$ $\sigma = .040$ $DW=2.3$ $AR(1,101) = 6.70[.01]$ $N(2) = 2.43$						

b) $di_{t-1} \rightarrow dx_t$

	dx_{t-1}	di_{t-1}	time effects			
Estimated coefficient	0.16	.12	.06	.01	-.05	-.002
"t" (absolute value)	(1.69)	(2.1)	(6.1)	(0.5)	(4.0)	(0.21)
$R^2 = .22$ $F(5,102) = 5.7[.00]$ $\sigma = .04$ $DW = 2.2$ $AR(1,101) = 4.29[0.04]$ $N(2) = 2.5$						

c) $dy_{t-1} \rightarrow dx_t$

	dx_{t-1}	dy_{t-1}	time effects			
Estimated coefficient	0.13	0.37	.05	.01	-.04	-.01
"t" (absolute value)	(1.28)	(2.04)	(5.7)	(0.6)	(3.82)	(0.11)
$R^2 = .22$ $F(5,102) = 5.69[.00]$ $\sigma = .040$ $DW=2.2$ $AR(1,101) = 5.2[.02]$ $N(2) = 3.72$						

The symbols dy, dx, dm, di stand for first log-differences in GDP per capita, exports, imports and gross fixed investment. The sub-index t indicates non-overlapping 4-year-averages for the corresponding variable along the 27-country sample. The time period considered goes between 1971 to 1992 (4 non-overlapping averages were computed). The numbers under the lags column are the estimated coefficients for the constant and dummy variables corresponding to the 1st, 2nd and 3rd lags. The estimation method is Ordinary Least Squares (OLS). F stands for the F (joint significance) test and σ denotes the average estimation error. $AR(1,..)$ is the first order autocorrelation statistics (Harvey (1981). $N()$ is the χ^2 Jarque-Bera (1980) statistic under the normality assumption.

TABLE 8

**GRANGER CAUSALITY TEST: dx_t
IVE
(108 observations)**

a) $dm_{t-1} \rightarrow dx_t$

	dx_{t-1}	dm_{t-1}	time effects			
Estimated coefficient	0.20	0.12	.05	.01	-.04	-.002
"t" (absolute value)	(1.7)	(1.73)	(5.8)	(0.53)	(3.8)	(0.02)
$\sigma = .040$ DW = 2.3 $AR\chi^2(1) = 4.71$ N(2) = 2.12 ARCH F(1,100) = 5.77 [0.02] HW F(7,94) = 0.60 [0.75]						

b) $di_{t-1} \rightarrow dx_t$

	dx_{t-1}	di_{t-1}	time effects			
Estimated coefficient	0.20	0.12	.05	.01	-.05	.002
"t" (absolute value)	(1.69)	(1.97)	(5.4)	(0.5)	(4.0)	(0.14)
$\sigma = .040$ DW = 2.3 $AR\chi^2(1) = 3.47$ N(2) = 2.21 ARCH F(1,100) = 4.81 [0.03] HW F(7,94) = 0.46 [0.85]						

c) $dy_{t-1} \rightarrow dx_t$

	dx_{t-1}	dy_{t-1}	time effects			
Estimated coefficient	0.17	.33	.05	.01	-.04	-.001
"t" (absolute value)	(1.34)	(1.78)	(5.14)	(.6)	(3.86)	(0.1)
$\sigma = .040$ DW = 2.3 $AR\chi^2(1) = 4.0$ N(2) = 3.3 ARCH F(1,100) = 4.52 [0.04] HW F(7,94) = 1.44 [0.20]						

The symbols dy, dx, dm, di stand for first log-differences in per capita GDP, exports, imports and gross fixed investment. The sub-index t indicates non-overlapping 4-year-averages for the corresponding variable along the 27-country sample. The time period considered goes between 1971 to 1992 (4 non-overlapping averages were computed). The numbers under the lags column are the estimated coefficients for the constant and dummy variables corresponding to the 1st, 2nd and 3rd lags. The estimation method is Instrumental Variables (IVE). σ denotes the average estimation error. $AR\chi^2(1)$ is the first order autocorrelation statistics (for IVE estimation). $N(\cdot)$ is the χ^2 Jarque-Bera (1980) statistics under the normality assumption. ARCH (1,.) is the F statistic for conditional autoregressive heteroscedasticity (of 1st order) and HW(.,.) is the White's F statistic for heteroscedasticity due to the square of regressors.

GRANGER CAUSALITY USING PANEL DATA

Caroll and Weill (1994) apply "causality" tests to a sample that includes both time series and cross-section observations (panel data). Their approach can be framed by noting that they estimate a regression which is encompassed by the next one,

$$y_{it} = \mu + y_{t-ji}' \beta + x_{t-ji}' \gamma + w_t' \delta + \alpha_i + u_{it} ; t=1...T \quad i=1...N \quad (1)$$

where j and l ($j, l > 0$) denote appropriate lags such that u_{it} results as innovation (given the information set).

Regarding eq.(1), the variable x (does not) Granger-causes y if the hypothesis $H_0: \gamma = 0$ can (cannot) be rejected. A symmetrical approach would test the causality of y on x .

Caroll and Weill analyze the causality between the average propensity to save and growth for a sample of different countries (i), and take the time observations (t) as nonoverlapping averages of k years. In this work, $k=5$, in order to isolate long run effects from cyclical(shorter) movements; moreover, taking nonoverlapping averages assume a lag effect of k years (on average). They also assume $l = j = 1$ in eq. (1) and restrict the time effects, w_t' , to dummy variables.

When an equation like (1) is estimated, two questions arise: i) the inclusion of "country specific effects" , α_i ;and ii) the estimation of a dynamic model since lagged explained variables are include as regressors. These problems are interrelated as we will show. They are also more critical when the panel has a short number of time observations (small T) - as it is often found in practice- for i), and many cross-section observations (large N) for ii), since there are also many α_i parameters to be estimated (for example, including country specific dummies). (See Hsiao, 1986)

An approach often suggested for static models to tackle ii) is to reformulate the model in differences thus eliminating α_i . However, when this approach is applied to a dynamic model like (1) OLS are not appropriate. Assuming $j = 1$ in (1) and taking first differences, it becomes,

$$\Delta y_{it} = \beta_1 \Delta y_{t-1i} + \gamma_1 \Delta x_{t-1i} + w_t^* \delta^* + v_{it} \quad (2)$$

where w_i^* , δ^* now include the time-effects for the model in differences. Since $v_{it} = u_{it} - u_{i,t-k}$, then $E(v_{it}, \Delta y_{t-k}) \neq 0$, and OLS estimators are biased. Therefore, instrumental variables estimators (IVE) are suggested; and appropriate IV are Δy_{t-k} or y_{t-k} . (See, Hsiao 1986). Both, OLS and IVE are presented by Carroll and Weil.

The approach of section 2 can be summarized as follows: a) the variables were defined as first differences of nonoverlapping averages of k years, and b) country specific effects α_i are assumed only in the levels of the variables (e.g. in the level in the per capita GDP), thus the equations estimated are of the following kind,:

$$\Delta y_{it}^k = \beta_k \Delta y_{t-k}^k + \gamma_k \Delta x_{t-k}^k + w_i^{**} \delta^{**} + \varepsilon_{it} \quad (3)$$

where $\varepsilon_{it} = u_{it} - u_{i,t-k}$ and

$$\Delta y_{it}^k = (y_{it} - y_{i,t-k})/k$$

$$\Delta y_{t-k}^k = (y_{t-k} - y_{t-2k})/k$$

$$\Delta x_{t-k}^k = (x_{t-k} - x_{t-2k})/k$$

An instrumental variable for Δy_{t-k}^k is,

$$\Delta y_{t-k}^{kIV} = (y_{t-(k+1)} - y_{t-(2k+1)})/k$$

Thus $E[\varepsilon_{it}, \Delta y_{t-k}^{kIV}] = 0$ (if autocorrelation is not present) and estimating (3) by IV give unbiased estimators of the coefficients which can be used to perform "causality" test.

Finally, it is worth noting that determining k may result somewhat arbitrary (when nonoverlapping averages of (fixed) k periods are used), in addition to the selection of k in practice. However, this question is mostly related to the probability of type II error (not reject H_0 when it is false, here not detect "causalities") due to inappropriate k . Instead, it is not critical when "causalities" are found in a particular sample, whichever the value k has fixed. The problem of generalizing results to other countries and other periods is not exclusive of this approach.

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