

**PRODUCTION 'ROUNDABOUTNESS' AND ECONOMIC
GROWTH: SOME EMPIRICAL EVIDENCE**

**CARLOS HUMBERTO ORTIZ Q.
PROFESOR
DEPARTAMENTO DE ECONOMÍA**

**SANTIAGO DE CALI
UNIVERSIDAD DEL VALLE
FACULTAD DE CIENCIAS SOCIALES Y ECONÓMICAS
CENTRO DE INVESTIGACIONES Y DOCUMENTACIÓN SOCIOECONÓMICA
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PRODUCTION ‘ROUNDABOUTNESS’ AND ECONOMIC GROWTH: SOME EMPIRICAL EVIDENCE*

by

Carlos H. Ortiz Q.

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1. INTRODUCTION

1.1. Objective and Theory

The explanation of the worldwide disparities in income and economic growth has become one of the central issues in the recent wave of endogenous growth literature. This paper is also focused on that topic. Our hypothesis is that a partial explanation of these disparities lies in the degree of maturity of the net of interindustry linkages is a significant element in the growth process.

It has been known for a long time that advanced industrialized countries enjoy a higher degree of technological interdependence across sectors and industries:

“Displayed in the input-output table, the pattern of transactions between industries and other major sectors of the system shows that the more developed the economy, the more its internal structure resembles that of other developed economies. (...). Recent advances in input-output analysis and in the bookkeeping of underdeveloped countries have made it possible to apply the technique to a number of these economies. Their input-output tables show that in addition to being smaller and poorer they have internal structures that are different, because they are incomplete, compared with the developed economies. From such comparative studies a fundamental analytical approach to the structure of economic development is now emerging” (W. Leontief, 1986, p. 163).

But the links between economic structure and growth had not been properly identified until recent developments in economic analysis made it possible for growth economists to use the concepts of externalities and specialization through expansion of varieties in mathematically tractable economic models.

Endogenous growth models centred on specialization have pointed out the role of expansion of varieties of goods and factors as a source of dynamic increasing returns. The leading papers on this subject have emphasized endogenous technological change (Romer, 1987, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1991). In this type of model, forward-looking entrepreneurs bear the responsibility of innovating by investing in R&D; they have incentives to do so because it is assumed that free patent mechanisms exist to enforce property rights on new designs. In contrast to this line of research, we develop a model where expansion of varieties is brought about by the copying and adaptation of other's ideas (Ortiz, 1993). In this model, the force driven growth is education; if workers invest in education they enable themselves to copy others ideas and also to adapt other's technologies. The fundamental assumption of our approach is that knowledge and technologies are not completely excludable, but the worker needs to be sufficiently educated for appropriation to occur.

Both kinds of models capture different mechanisms in the process of economic growth. The assumption of knowledge excludability by patent is more appropriate for modelling the process of R&D in industrialized countries. Our model, on the other hand, is perhaps more suitable to explain economic development through technological development in non – industrialized countries.

Both kinds of models stress the costs associated with technological diversification. Models of endogenous technological change emphasize the investment cost in R&D; our model emphasizes the investment costs in education. Thus, it is clear that these models omit the role of knowledge externalities associated with the process of economic diversification¹. However, knowledge may be non-rival and non-excludable, thus technological breakthroughs may be diffused with no cost (or negligible cost) to the whole economy. These externalities then become a potential source of aggregate increasing returns which may induce sustained economic growth at increasing returns which may induce sustained economic growth at increasing rates. As is well known, the seminal paper in the new growth literature models this intuition (Romer, 1986). Moreover, using time series from 1700 to 1979 for the world leading capitalist countries, Romer finds that the hypothesis of increasing long-run growth rates of per capita GDP is not obviously contradicted by the data.

In line with Romer's work, the purpose of this paper is to explore the cross-country relationship between economic structure diversification and economic growth. Our hypothesis is that the social division of work increases total factor productivity and the rate of economic growth.

In order to support this hypothesis we will refer the reader to the supply side of our aggregate output function of a competitive economy where the interdependence of intermediate goods is taken as given by firms, the final good technology exhibits constant returns in primary factors, but increasing returns in primary factors and the number of varieties. If there are no costs in appropriating at least some of the new technologies, it follows that technological interdependence might be directly associated with economic growth. This feature must be true both in time series and cross- country data.

1.2 Related Empirical Research and Estimation Strategy

Existing empirical research has already reported significant evidence for the existence of external economies across industries in West Germany, France, the United Kingdom and Belgium (Caballero and Lyons, 1990). They also report very little evidence of internal increasing returns economies in the industries of these countries. Besides, they show that failure to take into account external economies at the industry level. These findings

¹ This is recognized by Romer in his seminal paper on growth and specialization: "The model (...) ignores increasing returns from investment in knowledge and external effects due to spillovers of knowledge. It focuses exclusively on the role of specialization. A more realistic and more ambitious model would examine both effects" (Romer, 1987, page 56).

suggests that external economies are an important part of aggregate increasing returns as emphasized in Romer's (1986) paper.

Building on Caballero and Lyons' paper, Bartelsman, Caballero and Lyons (1991) have explored the relationship between input-output linkages and total factor productivity. They found that external effects operate through interindustry linkages in United States manufacturing industry. Specifically they found evidence that the relationship between an industry and its suppliers of intermediate inputs is important in the transmission of external effects leading to the generation of externalities are thought to be specialization through input diversification and knowledge embodied in intermediate products.

In this paper we want to go a step further to test the relationship between economic diversification and economic growth. Now, how can we test this theory? A direct approach would involve constructing an index of good variety across countries. But then one must solve the difficult problem of comparability; this task is not within our possibilities. However, we can circumvent this problem by using instead direct and indirect measures of production roundaboutness. Notice then that our approach rests on the assumption that economic diversification and technological interdependence are intimately related. Such an assumption is consistent with the stylized fact that a country's production structure becomes more roundabout as industrialization takes place.

As is well known, cross-country regressions are usually subject to problems of heteroscedasticity and measurement error that might render invalid estimates. Cross-country analysis is also subject to problems of heterogeneity across countries (Stern, 1989). In the spirit of Levine and Renelt's (1992) sensitivity analysis of cross-country growth regressions, we will try to minimize the heterogeneity problem by including a basic set of regressors that have proved to be robustly correlated with economic growth. Hence, our objective is to check whether our measures of roundaboutness appear to be significantly correlated with economic growth after controlling for the effects of Levine and Renelt's basic set of regressors.

2. CROSS-COUNTRY GROWTH REGRESSIONS

2.1. Indirect Measures of Production Roundaboutness

Our dependent variable is the annual growth rate of real per capita GDP from 1960 to 1988 (G). This is calculated from Summers and Heston's data set (Summers and Heston, 1991) for a sub-set of 48 countries [see Table 7 in the Appendix].

Direct measures of the degree of interindustry integration are difficult to obtain. Indeed we obtained comparable direct measures for only nine countries. Hence, we will postpone the analysis of this information until section 2.2. Here we will use instead two proxies which are likely to be closely correlated with production roundaboutness: the ratio of intermediate consumption to gross output for the manufacturing sector in 1980 (IOMAN). (The term IO

stands for aggregate input-output coefficient in the manufacturing sector.) These variables were calculated for 48 countries from the United Nations' *National Account Statistics*; we chose the year 1980 because information for all countries in our sample is not available for earlier years.

Levine and Renelt's basic set of regressors are the following: real gross domestic product per capita in 1960 (RGDP60), the ratio of investment to GDP (I), the secondary-school enrolment ratio in 1960 (SEC60), and the average annual growth rate of population (GN). These variables are thought to be robustly correlated with the growth rate and have been theoretically motivated by many models in the growth literature. We also add an index of openness to this basic set of regressors: the average ratio of the sum of exports and imports to GDP (OPEN).

All this data is reported in Table 7 in the Appendix. All variables with exception of IO and IOMAN are taken or calculated from Summers and Heston (1991). We first estimate linear regressions by ordinary least squares. Because there is evidence of heteroscedasticity, we check the significance of our coefficients by using White's (1980) heteroscedasticity-consistent variance-covariance matrix. Hence we only report t-statistics based on this matrix. The results are shown in Table 1.

Regression (1) shows that the aggregate input-output coefficient (IO) does not seem to be correlated with economic growth, although the corresponding slope coefficient has the right sign. However, the input-output coefficient in the manufacturing sector (IOMAN) seems to be strongly correlated with economic growth.

TABLE 1
Regressions for Per Capita GDP Growth 1960-1988

Ordinary least squares estimation based on White's (1980) heteroscedasticity-consistent covariance matrix (t-statistics in parentheses)

Equation	(1)	(2)	(3)	(4)
Constant	-4.81* (-2.98)	-1.16 (-0.95)	-4.75* (-3.18)	-5.84* (-3.87)
RGDP60	-0.31E-3* (-1.82)	-0.35E-3** (-1.79)	-0.31E-3* (-2.02)	-0.22E-3* (-2.50)
I	0.15* (3.86)	0.13* (3.43)	0.15* (4.94)	0.15* (6.93)
IO	4.2E-3 (0.14)	0.04 (1.22)	---	---
IOMAN	0.08* (3.37)	---	0.08* (3.54)	0.09* (3.62)
SEC60	-3.8E-3 (-0.19)	-4.2E-3 (-0.19)	-2.4E-3 (-0.12)	---
OPEN	3.0E-3	0.01	2.3E-3	---

	(0.34)	(1.18)	(0.28)	
GN	-0.27	-0.17	-0.26	---
	(-1.63)	(-0.86)	(-1.62)	
R ²	0.674	0.607	0.678	0.648
S.E.	1.037	1.123	1.001	0.997
Sample	45	45	47	48

Note

* : coefficient statistically significant at the 5% level (two-tailed test).

** : coefficient statistically significant at the 10% level (two-tailed test).

Because both IO and IOMAN are proxies for production roundaboutness, we drop the regressor IOMAN in regression (2). This regression shows again that the slope coefficient on IO does not appear to be significant. In regression (3) we only use IOMAN as regressor, the slope coefficient corresponding to this regressor has the expected positive sign and is statistically significant.

The initial level of real income per capita (RGDP60), and the average investment ratio (I) are both significant and also appear with the expected signs. The former captures any tendency for catching up, whilst the investment rate should be positively correlated with economic growth for obvious reasons. These two variables appear as strongly robust in Levine and Renelt's (1992) analysis of cross-country regressions.

The school-enrolment ratio (SEC60), the index of openness (OPEN) and the growth rate of population (GN) do not appear to be significantly correlated with economic growth in our sample². They are not significant either as a set. Hence in regression (4) we exclude these regressors and find that the regressors RGDP60, I and IOMAN explain 65% of the total variation of cross-country economic growth in our sample.

Why does IOMAN seem to be correlated with economic growth whilst the aggregate measure IO, does not seem to be? This is particularly interesting if one takes into account that IO shows a higher degree of variation than IOMAN in our sample: the respective coefficients of variation are 0.21 and 0.10. We will advance two tentative explanations. The first has to do with the characteristics of these proxies; it is obvious that IO is more sensitive to composition problems as it is a weighted average of all the ratios of intermediate consumption to gross output across sectors. Hence, IO may be subject to greater measurement error which renders this variable less reliable as a proxy for economic interdependence. The second reason is based on Rebelo's analysis of two-sector models of

² This is probably due to the smallness of our sample and the inclusion of small economies and oil exporting countries. Excluding these countries reduces further our sample and does not modify the initial result.

economic growth characterized by linearly homogeneous technologies (Rebelo, 1991). In this paper Rebelo proves that the requisite for sustained economic growth at a constant rate in a competitive environment is the existence of a “core” set of reproducible factors whose technologies are characterized by constant returns to scale. Hence, it follows that increasing returns to scale technologies in the “core” set of reproducible factors yields increasing growth rates, as in Romer’s model of knowledge externalities (Romer, 1986). This result may explain why the relevant proxy of economic integration for explaining economic growth is the manufacturing index (IOMAN). After all, the manufacturing sector is by definition the sector that provides most intermediate and capital goods in the economy. Additionally, the manufacturing sector is an intensive user of manufacturing intermediates, so that the growth externalities of input-output linkages identified by Bartelsman, Caballero and Lyons (1991) are likely to accrue primarily to the manufacturing sector.

If Rebelo’s and Romer’s models provide the clue for understanding the strongly positive association between the degree of economic roundaboutness and economic performance, here we have further evidence that economic structure matters for economic development.

Some caution is required, however, interpreting our results. Our proxies may be related to the degree of technological interdependence, but they also may reflect the degree of industrialization or related processes:

“As countries industrialize, their productive structures become more “roundabout” in the sense that a higher proportion of output is sold to other producers rather than to final users” (H. Chenery and M. Syrquin, “Typical Patterns of Transformation”, Chapter 3, page 57, in H. Chenery, S. Robinson and M. Syrquin, 1986).

Therefore, we would like to check whether our results are reproduced when a direct measure of economic integration is used instead of our proxy IOMAN. This leads us to the next section.

2.2 Direct Measures of Production Roundaboutness

Based on Kubo’s work on cross-country comparisons of interindustry linkages (Kubo, 1985), Kubo, De Melo, Robinson and Syrquin (1986) calculated comparable indices of aggregate interindustry linkages using information from 30 input-output matrices for nine countries and different years from 1950 to 1975.

The procedure to calculate these indices was the following. First, the authors rearranged each matrix into 14 comparable economic sectors and calculated the matrix of technical coefficients $\mathbf{A} = [a_{ij}]$, where a_{ij} is the technical coefficient measuring the amount (in value terms) of input i which is consumed in the production process of one unit of good j . Subsequently, they calculated the Leontief matrix, $\mathbf{L} = \mathbf{I} - \mathbf{A}$ where $\mathbf{I}$ denotes the identity matrix of the same order as matrix $\mathbf{A}$. Finally they obtained an index of overall linkages

(OL) as follows: $(OL) = \mathbf{f}' (\mathbf{L}')^{-1} \mathbf{i}$, where (OL) is a scalar, $\mathbf{f}$ is a 14x1 weight vector whose elements add up to 1, $\mathbf{i}$ is a 14x1 unit vector, the apostrophe (') denotes matrix transposition, and the power -1 denotes matrix inversion. Let us decompose this expression: $(\mathbf{L}')^{-1} \mathbf{i}$ is a 14x1 vector whose elements measure the degree of backward technological integration of the corresponding sectors, i.e. each element measures the proportion of gross output which is produced in the economy per unit value of final demand in the corresponding sector. The final expression (OL) is then a weighted average of these measures, where the weights are taken from the representative structure of the final demand vector for a semi-industrial country (see Chenery, Robinson and Syrquin, Chapter 4, 1986). These authors also obtain an index of domestic linkages (DL) by excluding imported intermediate inputs from the input-output matrix, the calculation is completely analogous to the previous one.

These measures of interindustry linkages are shown in Table 2, where we also show the equivalent annual growth rates of per capita GDP during 10 years (G10), the real per capita GDP (RGDP), the secondary-school enrolment ratio (SEC), the index of openness (OPEN), the equivalent annual growth rate of population in the following decade (GN10), and the average investment ratio in the next decade (I10). The choice of variables was determined by the same reasons stated in the Introduction. Sources and explanations of these variables are provided in the table.

Table 2 contains a small unbalanced panel. Using this information we run the growth regressions in Table 3. We estimate by ordinary least squares. Since we cannot reject the assumption of homoscedasticity, the associated OLS covariance matrix is used to calculate significance levels. The first three regressions use the measure of overall linkages (OL), whilst the last three use the measure of domestic linkages (DL). Because of the oil shocks of the 70's we add an interactive dummy in order to account for the apparent downward jump of growth rates during this period. It is likely that the oil shocks reduced the positive externalities of interindustry linkages because oil is perhaps the most important intermediate input for the current technology³. In the first and fourth regressions we also add country dummies in order to capture possible fixed effects. However, none of the country dummies appears to be significant, either in regressions (1) or in regression (4). The country dummies are not jointly significant either. When they are excluded we find that the measures of interindustry linkages appear to be strongly correlated with economic growth [see regressions (2) and (5)].

³ Without a dummy for the seventies our regressions exhibit lower determination coefficients, but the significance of other regressors does not change significantly.

Table 2
Unbalanced Data Set

Sample: 9 Countries, 30 Observations, Different periods

Economy	Year	G10	OL	DL	RGDP	SEC	OPEN	GN10	I10
			%	%	1985 US\$	%	%	%	%
Colombia	1953	0.80	50.0	37.2	1760	7	17.0	0.80	21.3
	1966	3.20	65.4	52.3	2126	19	15.5	3.20	17.7
	1970	3.39	69.0	53.9	2387	25	16.9	3.39	16.6
Mexico	1950	0.80	50.0	37.2	1760	7	17.0	0.80	21.3
	1960	3.53	68.9	51.3	2870	11	11.7	3.53	18.7
	1970	3.55	63.9	52.0	4061	22	10.1	3.55	21.6
	1975	1.15	69.5	54.2	4755	35	11.8	1.15	21.4
Turkey	1963	3.32	52.1	46.4	1884	16	7.7	3.32	18.9
	1968	3.78	56.7	51.5	2181	21	7.0	3.78	22.4
	1973	1.62	59.6	52.8	2612	28	9.3	1.62	23.8
Yugos-lavia	1962	5.71	82.2	67.9	1815	60	12.7	5.71	37.2
	1966	4.97	79.5	61.9	2324	64	16.4	4.97	35.4
	1972	3.78	87.3	59.4	3126	70	22.3	3.78	36.5
Japan	1955	8.26	89.9	81.3	1865	70	7.6	8.26	23.3
	1960	9.49	94.5	82.7	2701	74	7.7	9.49	29.5
	1965	6.62	94.6a	82.4	4125	82	9.1	6.62	33.5
	1970	3.70	106.3	88.7	6688	86	10.9	3.70	34.2
Korea	1963	7.44	89.9	60.9	1041	31	15.2	7.44	22.4
	1970	5.82	89.8	58.7	1722	42	21.7	5.82	29.3
	1973	5.22	92.8	54.6	2133	50	30.2	5.22	29.6
Taiwan	1956	4.92	76.5	42.6	852	34	17.1	4.92	13.6
	1961	7.21	85.9	55.0	1001	38	18.4	7.21	18.4
	1966	7.48	92.9	55.7	1377	43	25.9	7.48	24.3
	1971	6.90	93.7	55.2	2099	48	33.1	6.90	28.2
Israel	1958	4.68	83.7	53.8	3575	44	22.3	4.68	30.3
	1965	4.73	78.6	50.5	5280	48	26.9	4.73	28.9
	1972	1.17	101.5	48.1	7643	60	39.4	1.17	26.1
Norway	1953	2.71	66.7	40.8	4709	46	34.7	2.71	32.7
	1961	3.61	77.9	47.8	5673	59	35.6	3.61	33.2
	1969	4.21	87.2	47.6	7628	76	41.0	4.21	34.6

Sources. **G10:** Equivalent annual growth rate of real gross domestic product per capita during 10 years (calculated from Summers and Heston, 1991). **OL:** Overall linkage measure; **DL:** Domestic linkage measure (Chenery et al., Table 7-3, 1986). See text for explanation on linkage measures. **RGDP:** Real gross domestic product per capita (Summers and Heston, 1991). **SEC:** Secondary-school enrolment ratio (taken or estimated from the World Bank's World Tables 1980 and 1983). **OPEN:** Openness measure, ratio of the sum of exports and imports to total supply on the domestic market (Chenery et al., Table 7-5, 1986). **I10:** Average Investment-to-GDP ratio during 10 years (calculated from Summers and Heston, 1991).

Note. a: Using Kubo's estimation (1985) we corrected this figure from Kubo, De Melo, Robinson and Syrquin (1968).

Table 3
Growth Regressions from Unbalanced Panel

Sample = 30 (t-statistics in parentheses)

Equation	(1)	(2)	(3)	(4)	(5)	(6)
Constant	4.39 (0.99)	-0.72 (-0.36)	-2.70* (-2.67)	-3.16 (-0.44)	-4.00 (-1.40)	-4.20* (-3.42)
RGDP	-.8E-3* (-2.02)	-.6E-3* (-3.61)	-.6E-3* (-5.68)	-.9E-3* (-2.25)	-.7E-3* (-4.81)	-.7E-3* (-5.39)
OL	0.07 (1.53)	0.13* (3.92)	0.12* (9.25)	--	--	--
OL*D70	-0.02* (-2.74)	-0.02* (-3.93)	-0.02* (-4.34)	--	--	--
DL	--	--		0.15 (1.84)	0.16* (3.60)	0.16* (8.72)
DL*D70	--	--		-0.02 (-1.60)	-0.02* (-2.77)	-0.02* (-2.91)
OPEN	-0.06 (-0.99)	-0.02 (-0.91)		0.06 (0.57)	0.14* (3.49)	0.13* (5.17)
SEC	4.6E-3 (0.09)	-4.9E-3 (-0.15)		0.04 (0.74)	0.02 (0.67)	
I10	0.06 (0.97)	-0.02 (-0.47)		-0.02 (-0.31)	-0.06 (-1.18)	
GN10	-1.78 (-2.09)	-0.48 (-1.24)		-0.26 (-0.22)	0.19 (0.55)	
México	1.63 (1.89)			1.72 (1.80)		
Turkey	-0.14			0.53		

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	(-0.13)			(0.40)		
Yugos-	-3.13			-1.69		
lavia	(-1.50)			(-0.66)		
Japan	-0.78			-1.52		
	(-0.33)			(-0.55)		
Korea	0.50			0.78		
	(0.28)			(0.49)		
Taiwan	2.02			1.39		
	(0.96)			(0.64)		
Israel	2.73			1.78		
	(1.45)			(0.77)		
Norway	-0.85			1.70		
	(-0.41)			(0.71)		
R ²	0.914	0.835	0.808	0.896	0.818	0.797
S.E.	0.921	1.019	1.011	1.015	1.071	1.061

* Coefficient significant at the 5% level (two-tailed test).

The initial level of per capita GDP (RGDP), and the 70's interactive dummy variables (OL*D70 and DL*D70) are also significant and exhibit the expected negative signs.

Interestingly, regressions (1) and (2) show that when the measure of overall linkages (OL) is included some of the traditional explanatory variables do not seem to be significant. However, regressions (5) and (6) show that the measure of openness (OPEN) appears to be significant when the measure of domestic linkages (DL) is included. Since the difference between the measures of overall linkages and domestic linkages is accounted for by the exclusion of imported intermediates, the previous result suggests that openness is correlated with economic growth to the extent in which it proxies the role of imported intermediates in the degree of economic integration. Now, by excluding the non significant regressors we are left with regressions (3) and (6). Again it is most interesting that these two regressions explain similar proportions of cross-country growth performance: around 80%.

The sets of excluded variables in going from regression (2) to regression (3), and from regression (5) to regression (6), do not appear to be statistically significant at the 5% level.

There is one reason to be uncomfortable with the last set of regressions. Our dependent variable is the annual growth rate calculated over a period of 10 years. We proceed in this way in order to eliminate, at least partially, the cyclical effects. However, the periods

between observations for the same country are usually smaller than 10 years (see Table 2). Hence the regressors may partially “explain” the behaviour of consecutive dependent variables, which introduces some correlation between regressors and disturbances of each country. Because of this feature we may obtain biased estimates of the regression coefficients.

We try to solve this problem by choosing only observations at the beginning of each decade for which there is available information. The cost of this procedure is the loss of observations. The new data set contains only 23 observations and is displayed in Table 4. Although the number of observations is not the same for each country, we call this data set “balanced” because the period between observations is the same for all countries in our sample. This use of the term is unconventional, but it is useful to distinguish this panel data from the panel in Table 2. The balanced panel contains the same set of variables as the unbalanced panel. Taking advantage of the strong time trend behaviour of the linkage measures (OL and DL), we estimated some of the new observations by linear interpolation or least squares from the original unbalanced panel.

The regressions corresponding to Table 4 are shown in Table 5. They yield the same results as the regressions in Table 3: the set of country dummies is not significant at conventional levels, and the measures of interindustry linkages (OL and DL) appear again with positive and significant coefficients. The initial level of per capita GDP.

(RGDP) is also significant and its coefficient appears with the expected negative sign. The other regressors of the basic set are not significant as a whole, except for the openness measure (OPEN) when accompanied with the index of domestic linkages (DL).

Table 4
Balanced Data Set
 Sample: 9 Countries, 23 Observations, Decadal Periods.

Economy	Year	G10 %	OL %	DL %	RGDP 1985 US\$	SEC %	OPEN %	I10 %	GN10 %
Colombia	1950	1.26	46.7	34.5	1653	5	17.0	21.6	3.11
	1960	2.45	58.1	44.7	1874	12	15.5	19.2	3.05
	1970	3.39	69.0	53.9	2387	25	16.9	16.6	1.99
México	1950	2.58	54.3	40.5	2224	5	14.8	16.4	3.26
	1960	3.53	68.9	51.3	2870	11	11.7	18.7	3.28
	1970	3.55	63.9	52.0	4061	22	10.1	21.6	2.93
Turkey	1960	3.23	50.1	45.1	1669	14	7.7	17.8	2.53
	1970	2.73	57.6	51.5	2293	27	7.0	23.0	2.41
Yugoslavia	1960	5.66	79.2	68.5	1690	58	12.7	37.7	1.02
	1970	4.62	84.9	60.3	2932	63	22.3	36.3	0.91
Japan	1950	7.80	84.0	78.3	1275	66	7.6	18.1	1.19
	1960	9.49	94.5	82.7	2701	74	7.7	29.5	1.04
	1970	3.70	106.3	88.7	6688	86	10.9	34.2	1.13
Korea	1960	6.43	88.8	63.0	923	27	15.2	18.0	2.58
	1970	5.82	89.8	58.7	1722	42	21.7	29.3	1.79
Taiwan	1950	4.35	71.4	41.7	630	30	17.1	11.1	3.73
	1960	6.64	83.1	49.4	964	37	18.4	17.5	3.12
	1970	7.52	94.9	57.1	1833	47	33.1	27.6	1.95
Israel	1960	5.31	81.6	52.8	3958	48	22.3	29.6	3.47
	1970	2.49	94.3	48.8	6645	57	39.4	28.0	2.69
Norway	1950	2.47	63.2	40.8	4263	42	34.7	32.7	0.93
	1960	3.61	76.0	45.0	5443	57	35.6	32.6	0.80
	1970	4.41	88.8	49.2	7761	84	41.0	34.8	0.54

Sources. G10: Equivalent annual growth rate of real gross domestic product per capita during 10 years (calculated from Summers and Heston, 1991). **OL:** Overall linkage measure; **DL:** Domestic linkage measure (taken or estimated from Chenery et al., Table 7-3. 1986). See text for explanation on linkage measures. **RGDP:** Real GDP per capita (Summers and Heston, 1991). **SEC:** Secondary-school enrolment ratio (taken or estimated from the World Bank's World Tables 1980 and 1983). **OPEN:** Openness measure, ratio of

the sum of exports and imports to total supply on the domestic market (Chenery et al., Table 7-5, 1986). **I10**: Average Investment-to-GDP ratio (Summers and Heston, 1991). **GN10**: Equivalent annual growth rate of population during 10 years (calculated from Summers and Heston, 1991).

Table 5
Growth Regressions from Balanced Panel
 Sample = 23
 (t-statistics in parentheses)

Equation	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-5.38* (-2.47)	-1.91 (-1.63)	-0.95 (-1.01)	-5.04 (-1.91)	-3.28* (-2.46)	-3.24 (-2.44)
RGDP	-1.4E-3* (-4.70)	-.6E-3* (-4.60)	-.7E-3* (-4.57)	-.9E-3* (-3.37)	-.7E-3* (-4.62)	-.7E-3* (-4.61)
OL	0.18* (4.13)	0.11* (6.68)	0.10* (5.52)	---	---	---
DL	---			0.18* (3.22)	0.14* (6.95)	0.14* (6.90)
OPEN	---			0.09	0.12*	0.12*
México	1.54 (1.88)			1.60 (1.54)		
Turkey	1.36 (1.50)			0.73 (0.60)		
Yugoslavia	-1.11 (-0.84)			-0.52 (-0.35)		
Japan	0.13 (0.09)			-0.05 (-0.02)		
Korea	-2.80 (-1.58)			0.09 (0.06)		
Taiwan	-1.89 (-1.24)			1.59 (1.35)		
Israel	0.70 (0.59)			2.02 (1.40)		

Norway	3.18* (3.01)			2.77 (1.77)		
R ²	0.877	0.716	0.644	0.851	0.741	0.739
S.E.	0.974	1.148	1.052	1.121	1.125	1.122

* Coefficient significant at the 5% level (two-tailed test).

Regressions (3) and (6) are estimated under the assumption of random effects in the countries intercept. We estimate by applying an equivalent procedure to generalized least squares (see, for instance, Johnston, 1984, ch. 10). The regression model is defined as usual by $y_{it} = W_{it}\beta + u_{it}$, where the independent variable, y_{it} , is the growth rate at time t in country i , w_{it} is the matrix of independent variables, β is the vector of coefficients, and $u_{it} = \alpha_i + \epsilon_{it}$ is the disturbance term composed of a fixed part plus a random component. In order to obtain the random effects estimator we calculate the means for countries as follows: $\bar{y}_i = (T_i)^{-1} \sum_t y_{it}$, where t goes from 1 to T_i , T_i being the number of observations for country i . Using this information the original observations are modified as follows: $\tilde{y}_{it} = y_{it} - \bar{y}_i$, where $\tilde{\alpha}_i = 1 - (\sigma^2_{\epsilon} / (\sigma^2_{\epsilon} + T_i \sigma^2_{\alpha}))^{1/2}$, σ^2_{ϵ} is the variance of the errors for the fixed effects regression, and $\sigma^2_{\epsilon} + \sigma^2_{\alpha}$ is the variance of the errors obtained from the regression with a single intercept. Finally we estimate $\tilde{y}_{it} = \tilde{\alpha}_i + e_{it}$ by OLS, which yields the random effects coefficients. Now, judging from the statistics, regressions (3) and (6) seem to yield more efficient estimates than the corresponding fixed effects estimates [regressions (1) and (4)]. However, this evidence is non conclusive. A hausman test for the regressor OL in regressions (1) and (3), on the null hypothesis that the random effects estimator is consistent and efficient, yields a test statistic of 2.02; the same test for the coefficient DL in regressions (4) and (6) yields a test statistic of 0.768. The Hausman statistics is asymptotically distributed as a normal (0,1) when the null hypothesis is valid. Thus the first test rejects marginally the random effects assumption at the 5% significance level; the second test fails to reject the random effects assumption. These results imply that the test is inconclusive. Moreover, since the Hausman test is only valid asymptotically, and our sample is small, its application here does not allow any definitive inference. However, for our purposes it is enough to show that all regressions in Table 5 yield similar estimates for the coefficients associated with the linkage measures and they appear to be strongly significant.

Finally we run pure cross-country growth regressions for the nine countries on which we have direct information on interindustry integration. For such a small sample the power of this exercise is minimal, but we avoid all sort of potential problems from time series estimation. The dependent variable is the annual growth rate of per capita GDP between 1950 and 1988 (G). The data set is displayed in Table 6.

Table 6
Cross-Section Data: 1950-1988
 Nine economies

Economy	G %	RGDP 60 1985 US\$	OL 70 %	DL 70 %	I %	GN %	SEC %	OPEN %
Colombia	2.05	1874	69.0	53.9	18.3	2.75	12.0	28.1
México	2.15	2870	63.9	52.0	18.8	3.20	11.0	24.8
Turkey	3.18	1669	57.6	51.5	19.1	2.75	14.0	20.7
Yugoslavia	3.80a	1690	84.9	60.3	36.9a	0.90a	58.0	41.1
Japan	6.13	2701	106.3	88.7	27.5	1.01	74.0	22.5
Korea	5.39b	958	89.8	58.7	22.0b	2.07b	27.5	41.3
Taiwan	5.97	964	94.9	57.1	19.6	2.54	37.0	52.3
Israel	3.76b	3958	94.3	48.8	27.5b	3.05b	48.0	62.6
Norway	3.36	5443	88.8	49.2	32.8	0.66	57.0	82.9

Sources.

G: Annual growth rate of per capita GDP 1950-1988 (Summers and Heston, 1991). **RGDP60:** Real per capita GDP in 1960 (Summers and Heston, 1991). **I:** Average investment ratio to GDP 1950-1988 (Summers and Heston, 1991). **GN:** Annual population growth rate (Summers and Heston). **OL70:** Overall linkage measure in 1970 (the linkage measures are taken or estimated from Chenery et al., 1986). **SEC:** secondary-school enrolment ratio in 1960 (World Tables, 1980 and 1983). **OPEN:** Average ratio of exports plus imports to Real GDP from 1955 to 1988 (World Bank, World Tables; information for Taiwan between 1980 and 1988 was taken from *National Income in Taiwan Area of the Republic of China, 1992*, Directorate-General of Budget, Accounting and Statistics, Executive Yuan).

Notes. **a:** 1953-1988; **b:** 1969-1987.

We obtain the following results:

- $$\begin{aligned}
 (1) \quad &= -1.76 \text{ CONST.} - 0.47\text{E-}3 \cdot \text{RGDP60} + 0.083 \cdot \text{OL70}, & R^2 = 0.842 \\
 &(-1.34) & (-2.75) & (5.32) & \text{S.E.} = 0.702 \\
 \\
 (2) \quad &= 0.12 \text{ CONST.} - 0.20\text{E-}3 \cdot \text{RGDP60} + 0.075 \cdot \text{DL70}, & R^2 = 0.446 \\
 &(0.05) & (-0.62) & (1.94) & \text{S.E.} = 1.316 \\
 \\
 (3) \quad &= -3.21 \text{ CONST.} - 0.69\text{E-}3 \cdot \text{RGDP60} + 0.108 \cdot \text{DL70}, \\
 &(-1.81) & (-2.95) & (4.41) \\
 & & & + 0.063 \cdot \text{OPEN}, & R^2 = 0.841
 \end{aligned}$$

(3.53)

S.E.= 0.771

*: Coefficient significant at the 5% level (two-tailed test).

Regression 1 shows that the measure of overall linkages in 1970 (OL70) appears with a positive and significant coefficient. By comparing regressions (2) and (3) we can see that the measure of domestic linkages in 1970 (DL70) appears to be significant if accompanied by the index of openness (OPEN). No other regressor reported in Table 6 seems to be significant when the set of regressors includes the level of per capita GDP in 1960 (RGDP60) and the measure of overall linkages in 1970 (OL70).

3. CONCLUDING COMMENTS

In this paper we explored the relationship between interindustry linkages, or production roundaboutness, and economic growth. We tried different ways of tackling this: first with indirect measures of roundaboutness and afterwards with direct measures.

We found that the cross-country relationship between production roundaboutness and economic growth appears to be robust. In all our regressions the indices of technological integration or their proxies have positive coefficients that seem to be strongly significant.

Our regressions provide some support to economic theories that emphasize the need for industrialization as a necessary condition for economic take-off and sustained economic growth. Recall that we found that the relevant proxy for economic integration as an “explanatory” variable of growth performance is the proxy for technological integration in the manufacturing sector (see section 2.1).

Our paper also sheds some light on the newly established wisdom that trade liberalization is a condition for improving economic performance. Our results suggest that trade liberalization might be an important condition for successful economic growth in so far as it leads to a more diversified and technologically integrated economic structure (see section 2.2). In that sense a policy of import substitution may be as effective if it achieves the same goal. The important issue seems to be whether the trade regime enhances the possibility of dynamic increasing returns by augmenting the degree of interindustry integration.

Due to the likely existence of positive externalities from technological integration, it is highly probable that government intervention is needed. Subsidies to activities leading to technological integration, like R&D and technological education, might achieve better results than direct government investment. However, in preindustrial stages of development direct public intervention may be unavoidable. Hopefully we will see further research on this topic in the near future.

Our research is clearly limited by the availability and quality of data. For our larger data set (see Table 7 in the Appendix) we are forced to use proxies for the degree of

technological integration (see section 2.1). We could improve the quality of the index of technological integration but only for a small sample (see Table 2). Hence, our results must be interpreted cautiously. It would be highly desirable to check the robustness of our findings for a larger set of countries using comparable direct measures of economic technological integration.

Appendix: Table 7
Cross-Section Data: 1960-1988
Sample: 48 Countries

Country	G %	RGDP60 86US\$	I %	IOMAN %	IOTOT %	SEC60 %	OPEN %	GN %
Benin	-0.4	1075	5.5	68.4	30.6	2	17	-.4
Botswana	6.2	474	23.9	74.5	42.2	1	44.1	3.2
Burkina Faso	1.8	346	16.7	64.1	31.8	1	8.7	2.3
Burundi	0.6	473	7.9	60.9	30.4	1	14.7	2
Cameroon	2.8	736	10.3	67.8	39	2	22	2.7
Cape Verde	1.9	893	28.6	58.7	32.8	n.a.	30	2.0
The Gambia	2.3	411	3.2	72.4	33.2	3	73.7	2.8
Ghana	-0.6	1049	7.6	53.1	28.1	5	26	2.6
Mauritius	2.8	2113	12.3	67.8	46.1	24	35.8	1.7
Nigeria	-0.4	1133	11.7	57.7	29.8	4	20.5	2.7
Rwanda	0.7	538	4.5	64.8	33.9	2	10.6	3.2
Sierra Leone	0.2	871	2.2	74	28.4	2	14.2	1.9
Sudan	-0.3	975	1.8	60.6	33.1	3	13.3	2.7
Swaziland	2.4	1182	22.9	73.1	49.5	5	49.1	3.2
Zimbabwe	1.1	937	17.6	63.6	49.9	6	32.5	3.4
Canada	2.7	7758	22.9	75.8	54.1	46	46	1.4
Costa Rica	2	2160	14.2	68.3	n.a.	21	32.0	2.7
El Salvador	1	1305	7.7	60.6	33.3	13	26.5	2.4
Jamaica	1	1829	21.6	73.2	56.5	45	54.3	1.5
Mexico	2	2870	19.6	58.6	37.1	11	9.2	2.8
Argentina	0.6	3381	11.8	58.4	n.a.	32	12.7	1.5
Bolivia	0.6	1142	16.8	64.7	36.8	12	21.8	2.5
Chile	1	3103	13.3	63.5	46.1	24	20.5	1.8
Colombia	2.3	1874	17.2	64.3	42	12	11.7	2.3
Ecuador	2.3	1461	24.8	64.8	46.1	12	19.7	2.9
Peru	1	2130	15.9	68	48.5	15	16.7	2.7
Uruguay	0.6	4401	15.7	62.6	45.9	37	15.5	0.6
Venezuela	1.4	3899	16.5	61.8	40	21	37.4	3.5
Bangladesh	0.5	621	5.9	69.1	31.4	8	7	2.6
Japan	5.5	2701	31	70.4	53.4	74	23.2	0.9
Jordan	2.1	1328	16.6	67.7	47.8	25	50	3.1

Korea,								
South Rep.	6.3	923	24.7	76.4	56.7	27	28	2.0
Sri Lanka	1.3	1389	21.2	43.5	31.6	27	18.1	1.9
Syria	3	1787	17.0	80.5	38.3	16	16.5	3.4
Austria	3.3	4476	27.5	64.4	49.1	50	60.9	0.3
Cyprus	4.9	2039	31.6	67	45	47	60	0.6
Denmark	2.6	5900	27.8	67.5	45.1	65	68.3	0.4
Finland	3.5	4718	34.2	69.3	50.7	74	54.6	0.4
France	3	5344	25.9	64.4	45.9	46	36.4	0.7
Germany,								
Fed. Rep.	2.7	6038	26.9	70.2	65.1	53	52.5	0.3
Iceland	3.3	5352	25.8	69.1	47.6	61	92.0	1.2
Netherlands	2.6	5587	24	72.6	48.2	58	91.8	0.9
Norway	3.7	5443	32.8	71.3	46.3	57	95.1	0.6
Portugal	4.3	1618	23.7	68.4	54.9	20	36.4	0.5
Spain	3.7	2701	26.2	63.1	48.3	23	22.5	0.9
Sweden	2.5	6483	22.7	65.9	48.9	55	65.7	0.4
New								
Zealand	1.1	7222	22	67.7	55.8	73	41.9	1.2
Fiji	1.3	2354	22.4	74.7	45.7	15	43.2	1.3

Notation and sources. **G**: Average annual growth rate of real gross domestic product per capita (Summers and Heston, 1991). **RGDP60**: Real gross domestic product in 1960 (Summers and Heston, 1991). **I**: average investment to GDP ratio (Summers and Heston, 1991). **IOMAN**: Aggregate input-output coefficient of the manufacturing sector in 1980; **IO**: Aggregate input-output coefficient of the manufacturing sector in Accounts Statistics, United Nations). **SEC60**: Secondary-school enrolment ratio in 1960 (World Tables 1980 and 1983, World Bank). **OPEN**: Average ratio of the sum of exports and imports to GDP (Summers and Heston, 1991). **GN**: Average annual growth rate of population (Summers and Heston, 1991).

Notes: (a) 1960-86, (b) 1965-88, c) 1960-85, d) 1960-87, n.a.: non available information.

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