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# INTERINDUSTRY LINKAGES AND ECONOMIC DEVELOPMENT: THE CASE OF BRAZIL RECONSIDERED

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## I. INTRODUCTION

The concept of linkages, made prominent by Hirschman [10], has attracted a great deal of attention from development scholars. The principal concern in applied research utilizing the linkages concept has been the identification of "key" sectors. These key sectors are those which display the greatest amount of linkage or interdependence with other sectors. This interdependence can take the form of either (1) "backward linkages," the use by a given sector of inputs produced by other sectors or (2) "forward linkages," the role of a given sector in supplying inputs to other sectors. The basis of this concern with identifying key sectors is that these activities should receive special attention in planning and development schemes, as they have the greatest ability to stimulate the growth and development of sectors above and beyond themselves. This is especially important in the Brazilian context, where some scholars have attributed the success of Brazil's industrialization to the rapid growth of linkage-intensive sectors [6].

Part of the appeal of Hirschman's linkages concept to development economists is related to the fact that input-output tables, readily available for many less developed countries, provide the data necessary to compute the forward and backward linkages for various sectors of the economy. The apparent simplicity and ease of application of the linkages concept to input-output models, however, has largely proven illusory, for many previous researchers have based their empirical estimates on mathematically inconsistent measures of backward, forward, and total linkages.

This paper presents one of the first attempts to empirically estimate linkages with the ground-breaking new method suggested by Cella [7]. These mathematically consistent measures of linkages are applied to the Brazilian economy, with a view to identifying key sectors.[1] In addition, following Locatelli [13] [14],

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[1] The exact definition of what constitutes a "key" sector has been fairly ambiguous in the literature. In the present context, it refers to a sector that scores high (relative to the economy-wide average) on the linkage indicator under discussion.

we assess the relationship between sectoral performance on linkages and other indicators of both sectoral performance (employment creation, domestic resource cost, wage income accruing to the poor, etc.) and sectoral priorities of policy-makers, such as the level of import protection received by sector. With this analysis, we are able to (1) assess the employment, efficiency, and distributive consequences of promoting key sectors of the economy and (2) determine whether or not the Brazilian model of economic development has truly been linkage-intensive.

This paper is organized as follows. First, the Cella method for measuring backward, forward, and total linkages is delineated. Second, the empirical results of the application of Cella's method to Brazilian data are discussed. Third, the relationship between a sector's performance on linkages and other indicators of sectoral performance (such as employment generation) is presented. Fourth, the linkage intensity of the Brazilian model of economic development is critically examined. A summary section concludes the paper.

## II. THE MEASUREMENT OF LINKAGES

The method proposed by Cella[2] to calculate linkages represents a clear improvement over earlier methodologies.[3] As a starting point Cella follows Schultz [16] in using the hypothetical extraction approach. More precisely, this approach involves assessing what sectoral production in the entire economy would be if sector $j$ neither bought inputs from other sectors nor sold any of its output to other sectors. The difference between this hypothetical output and observed sectoral production indicates the total linkages of sector $j$.

Thus, the total linkages ($TL$) of the $n$ productive sectors can be represented by

$$TL = i'(q - \bar{q}), \tag{1}$$

where $i'$ is a unitary vector, $q$ is a vector of actual production, and $\bar{q}$ is a vector of production derived from the hypothetical extraction method. In the context of a two-sector economy, the output of sector 1 composed of $m$ industries ($q_1$) and sector 2 composed of $n-m$ industries ($q_2$) can be represented as

$$\begin{aligned} q_1 &= A_{11}q_1 + A_{12}q_2 + f_1, \\ q_2 &= A_{21}q_1 + A_{22}q_2 + f_2, \end{aligned} \tag{2}$$

where $A_{ij}$ is an input coefficient matrix and $f_i$ is a final demand vector for the product of sector $i$. $\bar{q}_1$ and $\bar{q}_2$ denote sectoral output that would occur if sectors 1 and 2 neither bought inputs from nor sold inputs to each other:

$$\begin{aligned} \bar{q}_1 &= A_{11}\bar{q}_1 + f_1 = B_{11}f_1, \\ \bar{q}_2 &= A_{22}\bar{q}_2 + f_2 = B_{22}f_2, \end{aligned} \tag{3}$$

[2] This section is largely based on Cella [7].

[3] For a review of previous attempts to measure linkages, and the conceptual problems with these measures, see Cella [7].

where $B_{rr} = (I - A_{rr})^{-1}$, for any $r$.

Following Cella, we can solve for $q_1$ and $q_2$ by

$$\begin{bmatrix} q_1 \\ q_2 \end{bmatrix} = \begin{bmatrix} H & HA_{12}B_{22} \\ B_{22}A_{21}H & B_{22}(I + A_{21}HA_{12}B_{22}) \end{bmatrix} \begin{bmatrix} f_1 \\ f_2 \end{bmatrix}, \tag{4}$$

where $H = (I - A_{11} - A_{12}B_{22}A_{21})^{-1}$.

Combining the results from equations (3) and (4), we have:

$$\begin{bmatrix} q_1 - \bar{q}_1 \\ q_2 - \bar{q}_2 \end{bmatrix} = \begin{bmatrix} H - B_{11} & HA_{12}B_{22} \\ B_{22}A_{21}H & B_{22}A_{21}HA_{12}B_{22} \end{bmatrix} \begin{bmatrix} f_1 \\ f_2 \end{bmatrix}. \tag{5}$$

In light of equation (1), total linkages are thus

$$\begin{aligned} TL &= [i'_a(H - B_{11}) + i'_b(B_{22}A_{21}H)]f_1 + [i'_a(HA_{12}B_{22}) \\ &\quad + i'_b(B_{22}A_{21}HA_{12}B_{22})]f_2 \\ &= BL + FL, \end{aligned} \tag{6}$$

where $i'_a$ and $i'_b$ are unitary vectors of the appropriate dimension. Our backward linkage measure $[i'_a(H - B_{11}) + i'_b(B_{22}A_{21}H)]f_1$ quantifies the inputs needed to support sector 1's final demand, while our forward linkage measure $[i'_a(HA_{12}B_{22}) + i'_b(B_{22}A_{21}HA_{12}B_{22})]f_2$ is dependent on both (1) the amount of sector 1 that is used to support the final demand of sector 2, measured by $i'_a(HA_{12}B_{22})f_2$ and (2) the feedback of this output in sector 1 on sector 2, quantified by $i'_b(B_{22}A_{21}HA_{12}B_{22})f_2$.

As Cella demonstrates, the scalar $(i'_aH + i'_bB_{22}A_{21}H)f_1$ is the measure of backward linkages currently in vogue a la Jones,[4] where $BL$ is taken to indicate the amount of direct and indirect inputs needed to sustain the output of sector 1. Cella's measure of $BL$ in equation (6) subtracts from this measure the scalar $i'_aB_{11}f_1$. Given that this scalar measures transactions that are purely internal to sector 1, it is clear that these transactions should be excluded from any measure of linkages.

In this paper we report empirical estimates of linkages based on the application of the Cella method to the 1975 input-output table of the Brazilian economy. These input-output tables were constructed by the Instituto Brasileiro de Geografia e Estatística (IBGE). The 261-by-123 matrix of inputs (261 products, 123 sectors) was pre-multiplied by the matrix allocating products to sectors (123 by 261) to form a 123-by-123 sectoral matrix. Linkage estimates for 120 of the 123 sectors of the economy are reported here, with finance, equipment leasing, and the dummy sector for repair pieces being deleted for reason of the special treatment of these sectors in the input-output table.

The linkage estimates presented in the following section only measure domestic linkages. That is, the input-output coefficients used to compute the linkage estimates do not include the imported inputs used to produce a sector's output. Similarly, the final demand vector does not incorporate final demand imports. In light of this, it is appropriate to note that our results are best suited for an ex-post analysis of linkages, that is, an analysis of which sectors have had the

[4] It should be noted that the Jones [12] measure of $BL$ assumes that $f_1$ is equal to unity.

TABLE I

STRUCTURE OF PRODUCTION (PERCENTAGE DISTRIBUTION)

| Sector | 1959 | 1970 | 1975 |
|---|---|---|---|
| 1. Agriculture | 16.23 | 11.11 | 9.43 |
| 2. Mining | 1.10 | 0.75 | 0.63 |
| 3. Nonmetallic minerals | 1.86 | 1.90 | 1.92 |
| 4. Metal products | 4.98 | 5.71 | 6.28 |
| 5. Machinery | 1.73 | 2.61 | 3.79 |
| 6. Electrical equipment | 1.87 | 2.14 | 2.40 |
| 7. Transport equipment | 3.38 | 3.80 | 4.24 |
| 8. Wood | 1.06 | 1.04 | 1.05 |
| 9. Wood products | 0.74 | 0.81 | 0.74 |
| 10. Paper | 1.26 | 1.09 | 1.10 |
| 11. Rubber | 1.02 | 0.77 | 0.79 |
| 12. Leather | 0.43 | 0.30 | 0.23 |
| 13. Chemicals | 7.22 | 5.09 | 7.36 |
| 14. Pharmaceuticals | 0.85 | 0.98 | 0.73 |
| 15. Cosmetics | 0.62 | 0.63 | 0.48 |
| 16. Plastics | 0.27 | 0.76 | 0.88 |
| 17. Textiles | 5.03 | 4.10 | 3.41 |
| 18. Clothing and footwear | 1.37 | 1.55 | 1.47 |
| 19. Food | 9.84 | 10.71 | 7.97 |
| 20. Beverages | 0.97 | 0.75 | 0.62 |
| 21. Tobacco | 0.45 | 0.45 | 0.39 |
| 22. Printing | 0.95 | 1.19 | 1.08 |
| 23. Other industrial products | 0.58 | 1.06 | 1.02 |
| 24. Public utilities | 0.93 | 2.25 | 2.32 |
| 25. Construction | 6.08 | 10.73 | 10.14 |
| 26. Trade margins | 16.17 | 18.56 | 14.98 |
| 27. Services | 13.01 | 9.14 | 14.53 |
| Total | 100.00 | 100.00 | 100.00 |

Source: [6, p. 280].

greatest actual linkages (given the current level of dependence on imports). This is in contrast to an analysis of what linkages might be if all inputs were supplied domestically ("potential linkages"). For relatively open economies, there can be a great difference in the linkage ranking of sectors, depending on whether imports are included or not. In the Brazilian case, however, imports are such a small portion of total sectoral supply that differing assumptions about imports have little effect on our linkage measures. For example, Locatelli [14] found a Spearman correlation coefficient of 0.93 between the measures of actual and potential backward linkages for the 1970 Brazilian economy. Hence, our results provide an excellent idea of the ranking of sectors in terms of potential linkages, even though we calculate actual linkages for each sector of the economy.

Before providing linkage estimates by sector, a quick overview of the structure of the Brazilian economy is in order. Table I provides data on the structure of production in the Brazilian economy for twenty-seven different sectors. As the table evinces, the rapid economic growth Brazil enjoyed in the 1960s and 1970s was accompanied by substantial changes in the structure of production. From 1959 to 1975, the share of agriculture and consumer nondurables decreased, while the share of output accounted for by capital goods, consumer durables, and intermediate goods rose [5]. Relative to other countries at its level of development (1985 per capita GNP equalled U.S.$1,640), Brazil has a much more unequal distribution of income. This is reflected in its structure of production, which is more heavily weighted in favor of consumer durables than other countries of similar per capita income [6].

Changes in the structure of the economy since the mid-1970s have been more modest than in earlier periods. Industry's share of Gross Domestic Product (GDP) has actually fallen, while the portion of economic activity accounted for by services has increased [4]. Agriculture's share of GDP has decreased by just a small amount, falling from 11.3 per cent in 1975 to 10.0 per cent in 1980 and 9.8 per cent in 1985 [4]. Given the relatively modest changes in productive structure since 1975, we can feel confident that the 1975 input-output tables provide a fairly reliable picture of the present structure of the Brazilian economy.

## III. EMPIRICAL RESULTS

Empirical estimates of total linkages (*TL*), backward linkages (*BL*), and forward linkages (*FL*) for 120 sectors of the Brazilian economy are presented in Table II. The results highlight the central role of the metallurgy industry in the Brazilian economy, as the primary iron and steel, and sheet metal sectors (sectors 22 and 23) both score very high on the *FL* measure. Of considerable surprise in Table II, however, is the high total linkages of many nonmanufacturing and "traditional" sectors, such as miscellaneous agriculture (sector 10), miscellaneous textiles (sector 82), and bus transportation (sector 114). The critical role of construction (sector 108) in stimulating other industries is also underscored, as this sector has the highest value of backward and total linkages. The figures in Table II also indicate that a high level of total linkages does not necessarily imply a high value for both forward and backward linkages; for example, all of construction's linkages are of the backward variety. *BL* and *FL* are not positively related; in fact, the correlation results reported in Table III indicate that sectors that tend to rank high in terms of backward linkages tend to be those sectors with the lowest amount of forward linkages.

The ranking of sectors by *BL* reveals the important role of transportation equipment (sectors 48–53) as a source of demand for other sectors' output. What is most noteworthy with respect to the ranking of sectors according to backward linkages, however, is the high linkages of both food products (sectors 85–99) and certain service sector activities, such as hotels and restaurants (sector 116). Thus, while the concept of linkages has often been used as a justification for the promotion of modern industrial sectors, our calculations reveal that these activities are not necessarily those with the greatest backward linkages.

Regarding forward linkages, it is clear that modern industrial activities such as metallurgy (sectors 21–31) and chemicals (sectors 64–73) play critical roles as

TABLE II

TOTAL, BACKWARD, AND FORWARD LINKAGES BY SECTOR, 1975

(1,000 cruzeiros)

| Sector | *BL* | Rank | *FL* | Rank | *TL* | Rank |
|---|---|---|---|---|---|---|
| 1. Forestry | 135 | (107) | 4,655 | (60) | 4,790 | (85) |
| 2. Fishing and hunting | 450 | (91) | 61 | (111) | 710 | (119) |
| 3. Coffee growing | 55 | (114) | 9,430 | (35) | 9,485 | (51) |
| 4. Sugarcane growing | 198 | (101) | 9,026 | (37) | 9,223 | (52) |
| 5. Rice farming | 702 | (79) | 3,976 | (61) | 4,678 | (87) |
| 6. Soybean, wheat farming | 1,568 | (60) | 10,942 | (26) | 12,511 | (36) |
| 7. Misc. crop growing | 1,030 | (74) | 2,440 | (76) | 3,470 | (100) |
| 8. Cattle raising | 1,639 | (59) | 7,901 | (42) | 9,540 | (50) |
| 9. Poultry | 3,528 | (38) | 5,246 | (56) | 8,774 | (56) |
| 10. Misc. agriculture | 11,161 | (11) | 54,973 | (2) | 66,135 | (4) |
| 11. Metallic mining | 1,767 | (54) | 2,591 | (73) | 4,357 | (92) |
| 12. Nonmetallic mining | 49 | (115) | 2,410 | (78) | 2,459 | (109) |
| 13. Petroleum, natural gas extraction | 124 | (109) | 3,067 | (70) | 3,190 | (104) |
| 14. Coal mining | 0 | (120) | 515 | (106) | 515 | (120) |
| 15. Cement | 12 | (119) | 10,767 | (28) | 10,779 | (44) |
| 16. Glass | 398 | (94) | 3,459 | (64) | 3,857 | (96) |
| 17. Nonmetallic mineral processing | 84 | (112) | 5,418 | (55) | 5,502 | (79) |
| 18. Cement structures | 23 | (117) | 11,113 | (24) | 11,136 | (42) |
| 19. Porcelain and ceramics | 330 | (97) | 9,519 | (32) | 9,849 | (49) |
| 20. Misc. nonmetallic mineral products | 121 | (110) | 2,872 | (72) | 2,993 | (106) |
| 21. Pig iron | 466 | (89) | 11,911 | (21) | 12,376 | (38) |
| 22. Primary iron and steel | 545 | (87) | 24,278 | (7) | 24,823 | (9) |
| 23. Sheet metal | 1,652 | (58) | 49,161 | (3) | 50,813 | (6) |
| 24. Cast iron and steel | 551 | (86) | 12,006 | (20) | 12,557 | (35) |
| 25. Nonferrous metal rolling, casting, extruding | 130 | (108) | 5,784 | (53) | 5,914 | (76) |
| 26. Nonferrous metals | 168 | (104) | 16,005 | (12) | 16,172 | (22) |
| 27. Metal wire | 700 | (80) | 12,482 | (18) | 13,182 | (30) |
| 28. Metal structures | 952 | (75) | 15,579 | (13) | 16,530 | (19) |
| 29. Stamped metal products | 907 | (76) | 6,325 | (50) | 7,232 | (69) |
| 30. Metal boxes, packaging | 139 | (106) | 6,122 | (51) | 6,261 | (72) |
| 31. Misc. metallurgical products and services | 3,011 | (43) | 9,548 | (31) | 12,558 | (34) |
| 32. Hydraulic pumps, engines | 1,107 | (73) | 977 | (98) | 2,084 | (113) |
| 33. Machine parts | 2,038 | (49) | 10,112 | (30) | 12,149 | (39) |
| 34. Turbines and boilers | 2,071 | (48) | 1,111 | (94) | 3,183 | (105) |

TABLE II (Continued)

| Sector | *BL* | Rank | *FL* | Rank | *TL* | Rank |
|---|---|---|---|---|---|---|
| 35. Ind. machines, equipment | 11,478 | (10) | 3,623 | (63) | 15,101 | (27) |
| 36. Agricultural machinery | 3,659 | (37) | 857 | (101) | 4,516 | (88) |
| 37. Earth-moving equipment | 6,337 | (21) | 1,045 | (96) | 7,382 | (68) |
| 38. Office equipment | 4,429 | (30) | 57 | (116) | 4,486 | (91) |
| 39. Maintenance, repair, installation of machines | 230 | (100) | 14,604 | (14) | 14,834 | (28) |
| 40. Electric energy equipment | 2,028 | (50) | 1,802 | (86) | 3,830 | (97) |
| 41. Electrical conductors | 581 | (85) | 7,126 | (47) | 7,707 | (61) |
| 42. Electric material, repair of electric appliances | 1,357 | (65) | 6,422 | (49) | 7,779 | (63) |
| 43. Electric material for vehicles | 447 | (92) | 4,844 | (58) | 5,291 | (80) |
| 44. Electric motors, appliances | 2,597 | (46) | 1,908 | (82) | 4,505 | (90) |
| 45. Electronic material | 368 | (96) | 1,876 | (83) | 2,244 | (111) |
| 46. Telephone, radio, TVs | 1,402 | (63) | 1,846 | (85) | 3,248 | (103) |
| 47. TV and radio receptors, sound equipment | 3,751 | (35) | 159 | (115) | 3,910 | (94) |
| 48. Automobiles | 33,239 | (3) | 249 | (113) | 33,488 | (8) |
| 49. Buses, trucks | 11,887 | (9) | 747 | (104) | 12,634 | (33) |
| 50. Vehicle motors, parts | 3,271 | (39) | 48,132 | (4) | 51,403 | (5) |
| 51. Naval industry | 3,023 | (42) | 1,714 | (87) | 4,737 | (86) |
| 52. Train production, repair | 1,286 | (67) | 956 | (99) | 2,242 | (112) |
| 53. Other vehicles | 1,263 | (68) | 1,324 | (91) | 2,587 | (108) |
| 54. Lumber | 445 | (93) | 16,113 | (11) | 16,558 | (18) |
| 55. Wooden structures | 670 | (82) | 8,029 | (41) | 8,700 | (58) |
| 56. Wooden furniture | 7,805 | (20) | 953 | (100) | 8,758 | (57) |
| 57. Metal furniture | 1,399 | (64) | 249 | (112) | 1,648 | (115) |
| 58. Pulp mills | 289 | (99) | 3,011 | (71) | 3,301 | (102) |
| 59. Paper and cardboard | 659 | (83) | 9,200 | (36) | 9,859 | (48) |
| 60. Objects of paper, cardboard | 692 | (81) | 8,467 | (38) | 9,159 | (53) |
| 61. Tires | 1,473 | (62) | 14,172 | (16) | 15,645 | (25) |
| 62. Rubber | 513 | (88) | 7,840 | (43) | 8,353 | (61) |
| 63. Leather and hides | 458 | (90) | 3,403 | (65) | 3,861 | (95) |
| 64. Chemical elements | 188 | (102) | 7,374 | (45) | 7,562 | (65) |
| 65. Alcohol from sugarcane and cereals | 399 | (94) | 1,046 | (95) | 1,445 | (117) |
| 66. Petroleum refining | 4,684 | (27) | 38,079 | (6) | 42,763 | (7) |

TABLE II (Continued)

| Sector | *BL* | Rank | *FL* | Rank | *TL* | Rank |
|---|---|---|---|---|---|---|
| 67. Petrochemicals | 290 | (98) | 8,352 | (39) | 8,642 | (59) |
| 68. Coal derivatives | 23 | (118) | 3,668 | (62) | 3,691 | (99) |
| 69. Resins, synthetic fibers | 46 | (116) | 17,404 | (9) | 17,449 | (16) |
| 70. Vegetable oil, unprocessed | 6,216 | (22) | 14,230 | (15) | 20,446 | (14) |
| 71. Paints, tints, solvents | 114 | (111) | 10,893 | (27) | 11,007 | (43) |
| 72. Fertilizers | 67 | (113) | 16,354 | (10) | 16,421 | (21) |
| 73. Misc. chemicals | 1,508 | (61) | 10,327 | (29) | 11,834 | (40) |
| 74. Pharmaceuticals | 2,571 | (47) | 3,358 | (67) | 5,879 | (77) |
| 75. Cosmetics | 5,855 | (24) | 836 | (102) | 6,691 | (70) |
| 76. Plastic sheets, plates | 162 | (105) | 5,769 | (54) | 5,930 | (75) |
| 77. Plastic articles | 892 | (77) | 11,873 | (22) | 12,765 | (32) |
| 78. Natural fiber mills | 1,786 | (53) | 9,443 | (34) | 11,229 | (41) |
| 79. Natural textile mills | 5,323 | (26) | 18,434 | (8) | 24,020 | (10) |
| 80. Synthetic textile mills | 4,665 | (28) | 12,436 | (19) | 17,101 | (17) |
| 81. Knitting | 3,225 | (40) | 2,528 | (75) | 5,752 | (78) |
| 82. Misc. textiles | 7,941 | (19) | 14,169 | (17) | 22,109 | (12) |
| 83. Clothing | 20,223 | (4) | 773 | (103) | 20,996 | (13) |
| 84. Footwear | 5,911 | (23) | 44 | (117) | 5,955 | (74) |
| 85. Coffee processing | 9,025 | (15) | 6,814 | (48) | 15,840 | (23) |
| 86. Coffee mills, instant coffee | 8,046 | (17) | 404 | (108) | 8,449 | (60) |
| 87. Rice processing | 9,554 | (14) | 1,012 | (97) | 10,565 | (46) |
| 88. Flour mills | 1,206 | (69) | 9,502 | (88) | 10,708 | (45) |
| 89. Vegetable, fruit canning | 3,810 | (34) | 506 | (107) | 4,315 | (93) |
| 90. Preparation of misc. food products of veg. oil | 2,737 | (45) | 2,427 | (77) | 5,164 | (82) |
| 91. Meat slaughtering | 18,203 | (5) | 4,706 | (59) | 22,909 | (11) |
| 92. Poultry slaughtering | 4,427 | (31) | 382 | (109) | 4,810 | (84) |
| 93. Dairy products | 13,939 | (8) | 2,589 | (74) | 16,528 | (20) |
| 94. Sugar mills | 8,041 | (18) | 7,216 | (46) | 15,257 | (26) |
| 95. Refined sugar | 4,522 | (29) | 1,539 | (88) | 6,061 | (73) |
| 96. Bakery products | 14,342 | (7) | 1,411 | (90) | 15,753 | (24) |
| 97. Vegetable oil, fat refining | 10,259 | (12) | 3,282 | (68) | 13,541 | (29) |
| 98. Animal feed | 874 | (78) | 8,144 | (40) | 9,018 | (54) |
| 99. Misc. food products | 5,611 | (25) | 1,848 | (84) | 7,459 | (66) |
| 100. Alcoholic beverages | 2,902 | (44) | 2,268 | (79) | 5,169 | (81) |
| 101. Nonalcoholic beverages | 1,668 | (57) | 1,160 | (93) | 2,828 | (107) |
| 102. Tobacco | 3,737 | (36) | 13 | (118) | 3,750 | (98) |

TABLE II (Continued)

| | Sector | *BL* | Rank | *FL* | Rank | *TL* | Rank |
|---|---|---|---|---|---|---|---|
| 103. | Books, magazines, newspapers | 1,801 | (52) | 573 | (105) | 2,374 | (110) |
| 104. | Other publishing industry products | 1,708 | (55) | 3,369 | (66) | 5,077 | (83) |
| 105. | Misc. industrial products | 4,229 | (32) | 3,169 | (69) | 7,397 | (67) |
| 106. | Electricity | 1,107 | (72) | 11,297 | (23) | 12,404 | (37) |
| 107. | Water works, supply | 1,688 | (56) | 190 | (114) | 1,879 | (114) |
| 108. | Construction | 157,254 | (1) | 0 | (120) | 157,254 | (1) |
| 109. | Distribution and trucking | 653 | (84) | 7,391 | (44) | 8,045 | (62) |
| 110. | Wholesale, retail trade | 10,256 | (13) | 58,813 | (1) | 69,069 | (3) |
| 111. | Train transportation | 1,162 | (70) | 2,213 | (80) | 3,375 | (101) |
| 112. | Boat transportation | 1,941 | (51) | 10,962 | (25) | 12,902 | (31) |
| 113. | Airline transportation | 3,023 | (41) | 1,488 | (89) | 4,511 | (89) |
| 114. | Bus transportation | 42,071 | (2) | 43,805 | (5) | 35,876 | (2) |
| 115. | Communications | 1,156 | (71) | 286 | (110) | 1,441 | (118) |
| 116. | Restaurants, hotels | 16,613 | (6) | 2,212 | (81) | 18,734 | (15) |
| 117. | Non-vehicle repairs | 178 | (103) | 1,310 | (92) | 1,488 | (116) |
| 118. | Vehicle repair | 1,344 | (66) | 5,109 | (57) | 6,453 | (71) |
| 119. | Hospitals | 8,798 | (16) | 2 | (119) | 8,800 | (55) |
| 120. | Misc. services | 4,168 | (33) | 6,010 | (52) | 10,178 | (47) |

TABLE III

CORRELATIONS BETWEEN LINKAGE MEASURES

| | *BL* | *FL* | *TL* | *BLVP* | *FLVP* | *TLVP* |
|---|---|---|---|---|---|---|
| *BL* | 1.000 | | | | | |
| *FL* | −0.249* | 1.000 | | | | |
| *TL* | 0.371* | 0.669* | 1.000 | | | |
| *BLVP* | 0.857* | −0.551* | 0.014 | 1.000 | | |
| *FLVP* | −0.640* | 0.773* | 0.266 | −0.677* | 1.000 | |
| *TLVP* | −0.180* | 0.488* | 0.437* | −0.120 | 0.717* | 1.000 |

Notes: 1. Figures represent Spearmen correlation coefficients.

2. Legend: *BL*=backward linkages, *FL*=forward linkages, *TL*=total linkages, *BLVP*=backward linkages per unit of sectoral production, *FLVP*=forward linkages per unit of sectoral production, *TLVP*=total linkages per unit of sectoral production.

* Significant at the 0.05 confidence level.

input suppliers in the Brazilian economy. Nevertheless, the forward linkages of nonindustrial sectors such as miscellaneous agriculture (sector 10) and wholesale and retail trade (sector 110) are also quite large. Hence, our results suggest that high backward and forward linkages are not the exclusive domain of modern manufacturing activities.

The figures in Table II do not provide a reliable guide to which sectors provide the greatest linkages per unit of output, since the linkage measures do not take into account the differing sizes of the sectors. In order to provide a measure of linkages per unit produced, the total, backward, and forward linkages in Table II were divided by the value of sectoral production.[5]

The normalized ranking of linkages in Table IV reiterates the ability of certain light industries, such as food products (sectors 85–99) to generate a high amount of backward linkages per unit produced. Among modern industrial sectors, the automobile industry (sector 48) generates the greatest amount of backward linkages per unit produced.

The forward linkage rankings reveal that rubber tires (sector 61) and metallurgy (sectors 21–31) generate the greatest amount of forward linkages per unit produced. Also scoring high on this criterion are some traditional industrial activities such as cement structures (sector 15) and flour (sector 88). Thus, while these sectors may not generate the greatest absolute amount of forward linkages, they still would play a critical role in a development strategy designed to encourage those sectors that are linkage-intensive.

The ranking of sectors according to total linkages per unit is also dominated by rubber tires (sector 61) and metallurgy (sectors 21–31). The support of the Brazilian state for these industrial activities may lead one to infer that Brazilian policymakers have consciously followed a linkage-intensive development strategy. This proposition is carefully examined in Section V, where the relationship between linkages and economic policy is assessed.

Of interest is a comparison of our results with those computed by other authors using alternative methods for calculating sectoral linkages in the Brazilian economy. Many of these studies [5] [6] have been conducted at a level of aggregation that precludes comparison with our results. For this reason, we concentrate on comparing our linkage estimates with those of Locatelli [13], who calculates backward and forward linkages for eighty-seven sectors of the economy from the 1970 input-output tables. These results are not strictly comparable to our results from 1975, given the greater level of disaggregation employed in our study.[6] Neverthe-

[5] The rational for this normalization is as follows. For each sector $j$, the final demand vector for the entire economy should be scaled down appropriately in order to have that final demand level which requires one unit of production in sector $j$. Assume that the sector under consideration is sector 1. In this case, to find the level of final demand requiring one unit of production in sector 1, we have $1 = A^1F(t_1)$, where $A^1$ is the first row of matrix $(I-A)^{-1}$, $F$ is the final demand vector for the entire economy, and $t_1$ is our unknown scalar. Given that $A^1F$ equals the output in sector 1, $q_1$, then $t_1$ must equal $1/q_1$. We are indebted to Guido Cella for this suggested method of normalization.

[6] It may seem problematic to compare results from input-output tables from 1970 and 1975,

TABLE IV

NORMALIZED RANKING OF LINKAGE MEASURES

| Sector | *BLVP* | Rank | *FLVP* | Rank | *TLVP* | Rank |
|---|---|---|---|---|---|---|
| 1. Forestry | 0.029 | (108) | 0.997 | (48) | 1.067 | (70) |
| 2. Fishing and hunting | 0.205 | (60) | 0.119 | (100) | 0.324 | (117) |
| 3. Coffee growing | 0.005 | (116) | 0.943 | (53) | 0.949 | (79) |
| 4. Sugarcane growing | 0.031 | (107) | 1.422 | (20) | 1.453 | (36) |
| 5. Rice farming | 0.131 | (72) | 0.744 | (64) | 0.875 | (90) |
| 6. Soybean, wheat farming | 0.183 | (64) | 1.278 | (29) | 1.461 | (33) |
| 7. Misc. crop growing | 0.174 | (66) | 0.412 | (78) | 0.586 | (110) |
| 8. Cattle raising | 0.126 | (73) | 0.609 | (66) | 0.735 | (102) |
| 9. Poultry | 0.670 | (27) | 0.995 | (49) | 1.664 | (16) |
| 10. Misc. agriculture | 0.120 | (75) | 0.589 | (67) | 0.708 | (105) |
| 11. Metallic mining | 0.339 | (49) | 0.497 | (73) | 0.837 | (95) |
| 12. Nonmetallic mining | 0.022 | (110) | 1.081 | (43) | 1.103 | (66) |
| 13. Petroleum, natural gas extraction | 0.050 | (98) | 1.241 | (34) | 1.291 | (50) |
| 14. Coal mining | 0 | (120) | 1.115 | (38) | 1.115 | (64) |
| 15. Cement | 0.002 | (119) | 1.456 | (16) | 1.458 | (34) |
| 16. Glass | 0.114 | (78) | 0.990 | (51) | 1.105 | (65) |
| 17. Nonmetallic mineral processing | 0.020 | (111) | 1.264 | (32) | 1.284 | (51) |
| 18. Cement structures | 0.004 | (117) | 1.688 | (8) | 1.691 | (12) |
| 19. Porcelain, ceramics | 0.044 | (100) | 1.278 | (30) | 1.322 | (46) |
| 20. Misc. nonmetallic mineral products | 0.051 | (96) | 1.215 | (36) | 1.266 | (52) |
| 21. Pig iron | 0.078 | (90) | 1.983 | (2) | 2.060 | (3) |
| 22. Primary iron, steel | 0.046 | (99) | 2.051 | (1) | 2.097 | (2) |
| 23. Sheet metal | 0.062 | (94) | 1.858 | (6) | 1.920 | (8) |
| 24. Cast iron, steel | 0.073 | (91) | 1.585 | (11) | 1.658 | (17) |
| 25. Nonferrous metal rolling, casting, extruding | 0.043 | (102) | 1.902 | (4) | 1.945 | (4) |
| 26. Nonferrous metals | 0.013 | (113) | 1.249 | (22) | 1.252 | (53) |
| 27. Metal wire | 0.092 | (86) | 1.638 | (10) | 1.730 | (11) |
| 28. Metal structures | 0.095 | (85) | 1.552 | (12) | 1.647 | (18) |

due to structural changes (especially due to import substitution) that may alter input-output coefficients. In the Brazilian case this is not much of a concern. A recent work by Araujo [1] that compares the 1970 and 1975 input-output tables is instructive on this point. Comparing the rank of sectors in terms of their sales and purchases with other sectors, he found relatively little change in the ranking of sectors. Thus, one can be fairly confident that the difference in the linkage estimates between 1970 and 1975 is due primarily to differences in the methodologies employed, rather than underlying changes in input-output coefficients.

TABLE IV (Continued)

| Sector | *BLVP* | Rank | *FLVP* | Rank | *TLVP* | Rank |
|---|---|---|---|---|---|---|
| 29. Stamped metal products | 0.193 | (62) | 1.346 | (25) | 1.539 | (26) |
| 30. Metal boxes, packaging | 0.043 | (101) | 1.892 | (5) | 1.935 | (6) |
| 31. Misc. metallurgical products, services | 0.313 | (50) | 0.993 | (50) | 1.307 | (48) |
| 32. Hydraulic pumps, engines | 0.658 | (28) | 0.580 | (69) | 1.307 | (55) |
| 33. Machine parts | 0.227 | (55) | 1.129 | (37) | 1.356 | (44) |
| 34. Turbines, boilers | 0.549 | (36) | 0.295 | (88) | 0.844 | (94) |
| 35. Ind. machines, equipment | 0.636 | (30) | 0.201 | (93) | 0.836 | (96) |
| 36. Agricultural machinery | 0.642 | (29) | 0.150 | (97) | 0.792 | (99) |
| 37. Earth-moving equipment | 0.702 | (25) | 0.116 | (101) | 0.818 | (97) |
| 38. Office equipment | 0.921 | (14) | 0.012 | (116) | 0.933 | (83) |
| 39. Maintenance, repair, installation of machines | 0.023 | (109) | 1.434 | (18) | 1.456 | (35) |
| 40. Electric energy equipment | 0.447 | (41) | 0.397 | (81) | 0.844 | (93) |
| 41. Electrical conductors | 0.118 | (76) | 1.447 | (17) | 1.564 | (22) |
| 42. Electric material, repair of electric appliances | 0.183 | (65) | 0.865 | (57) | 1.048 | (69) |
| 43. Electric material for vehicles | 0.136 | (71) | 1.477 | (15) | 1.613 | (20) |
| 44. Electric motors, appliances | 0.555 | (35) | 0.407 | (79) | 0.962 | (77) |
| 45. Electronic material | 0.154 | (67) | 0.784 | (63) | 0.937 | (82) |
| 46. Telephones, radios, TVs | 0.231 | (54) | 0.303 | (87) | 0.534 | (112) |
| 47. TV and radio receptors, sound equipment | 0.622 | (31) | 0.026 | (113) | 0.648 | (107) |
| 48. Automobiles | 1.666 | (2) | 0.012 | (115) | 1.679 | (14) |
| 49. Buses, trucks | 1.317 | (3) | 0.083 | (108) | 1.400 | (39) |
| 50. Vehicle motors, parts | 0.114 | (79) | 1.671 | (9) | 1.785 | (9) |
| 51. Naval industry | 0.568 | (34) | 0.322 | (85) | 0.890 | (87) |
| 52. Train production, repair | 0.386 | (47) | 0.287 | (89) | 0.674 | (106) |
| 53. Other vehicles | 0.397 | (46) | 0.416 | (77) | 0.813 | (98) |
| 54. Lumber | 0.039 | (103) | 1.397 | (21) | 1.435 | (37) |
| 55. Wooden structures | 0.117 | (77) | 1.396 | (22) | 1.513 | (29) |
| 56. Wooden furniture | 0.757 | (21) | 0.092 | (106) | 0.850 | (91) |
| 57. Metal furniture | 0.752 | (22) | 0.134 | (98) | 0.886 | (89) |
| 58. Pulp mills | 0.105 | (80) | 1.095 | (42) | 1.200 | (58) |
| 59. Paper and cardboard | 0.079 | (88) | 1.107 | (40) | 1.187 | (60) |
| 60. Objects of paper, cardboard | 0.100 | (81) | 1.218 | (35) | 1.318 | (47) |
| 61. Tires | 0.202 | (61) | 1.942 | (3) | 2.144 | (1) |
| 62. Rubber | 0.091 | (87) | 1.388 | (23) | 1.479 | (31) |
| 63. Leather and hides | 0.121 | (74) | 0.900 | (54) | 1.022 | (71) |
| 64. Chemical elements | 0.035 | (104) | 1.377 | (24) | 1.412 | (38) |

TABLE IV (Continued)

| Sector | *BLVP* | Rank | *FLVP* | Rank | *TLVP* | Rank |
|---|---|---|---|---|---|---|
| 65. Alcohol from sugarcane and cereals | 0.419 | (43) | 1.100 | (41) | 1.519 | (28) |
| 66. Petroleum refining | 0.099 | (83) | 0.803 | (61) | 0.902 | (85) |
| 67. Petrochemicals | 0.033 | (105) | 0.958 | (52) | 0.991 | (74) |
| 68. Coal derivatives | 0.010 | (114) | 1.540 | (13) | 1.550 | (25) |
| 69. Resins, synthetic fibers | 0.003 | (118) | 1.298 | (27) | 1.301 | (49) |
| 70. Vegetable oil, unprocessed | 0.472 | (40) | 1.079 | (44) | 1.551 | (24) |
| 71. Paints, tints, solvents | 0.016 | (112) | 1.519 | (14) | 1.535 | (27) |
| 72. Fertilizers | 0.005 | (115) | 1.333 | (26) | 1.338 | (45) |
| 73. Misc. chemicals | 0.152 | (69) | 1.041 | (47) | 1.193 | (59) |
| 74. Pharmaceuticals | 0.212 | (58) | 0.282 | (90) | 0.493 | (114) |
| 75. Cosmetics | 0.740 | (23) | 0.106 | (104) | 0.850 | (92) |
| 76. Plastic sheets, plates | 0.031 | (106) | 1.115 | (39) | 1.146 | (62) |
| 77. Plastic articles | 0.097 | (84) | 1.290 | (28) | 1.387 | (40) |
| 78. Natural fiber mills | 0.241 | (53) | 1.272 | (31) | 1.513 | (30) |
| 79. Natural textile mills | 0.310 | (51) | 1.074 | (46) | 1.384 | (41) |
| 80. Synthetic textile mills | 0.402 | (45) | 1.075 | (45) | 1.478 | (32) |
| 81. Knitting | 0.877 | (16) | 0.688 | (65) | 1.565 | (23) |
| 82. Misc. textiles | 0.495 | (38) | 0.884 | (56) | 1.379 | (42) |
| 83. Clothing | 1.156 | (7) | 0.044 | (111) | 1.200 | (57) |
| 84. Footwear | 0.887 | (15) | 0.007 | (117) | 0.893 | (86) |
| 85. Coffee processing | 0.704 | (24) | 0.532 | (70) | 1.236 | (56) |
| 86. Coffee mills, instant coffee | 1.297 | (4) | 0.065 | (109) | 1.362 | (43) |
| 87. Rice processing | 1.064 | (9) | 0.113 | (102) | 1.177 | (61) |
| 88. Flour mills | 0.219 | (56) | 1.722 | (7) | 1.941 | (5) |
| 89. Vegetable, fruit canning | 0.934 | (12) | 0.124 | (99) | 1.058 | (67) |
| 90. Preparation of misc. food products of veg. oil | 0.597 | (32) | 0.530 | (77) | 1.126 | (63) |
| 91. Slaughtering of meat | 0.762 | (20) | 0.197 | (94) | 0.959 | (78) |
| 92. Poultry slaughtering | 1.772 | (1) | 0.153 | (96) | 1.925 | (7) |
| 93. Dairy products | 0.848 | (17) | 0.158 | (95) | 1.006 | (72) |
| 94. Sugar mills | 0.923 | (13) | 0.829 | (58) | 1.752 | (10) |
| 95. Sugar refining | 1.257 | (6) | 0.428 | (75) | 1.685 | (13) |
| 96. Bakery products | 1.141 | (8) | 0.112 | (103) | 1.253 | (54) |
| 97. Vegetable oil, fat refining | 1.261 | (5) | 0.403 | (80) | 1.664 | (15) |
| 98. Animal feed | 0.153 | (68) | 1.429 | (19) | 1.583 | (21) |
| 99. Misc. food products | 0.795 | (18) | 0.262 | (91) | 1.058 | (68) |
| 100. Alcoholic beverages | 0.412 | (44) | 0.322 | (86) | 0.734 | (103) |
| 101. Nonalcoholic beverages | 0.536 | (37) | 0.373 | (82) | 0.909 | (84) |
| 102. Tobacco industry | 0.586 | (33) | 0.002 | (118) | 0.588 | (109) |

TABLE IV (Continued)

| Sector | *BLVP* | Rank | *FLVP* | Rank | *TLVP* | Rank |
|---|---|---|---|---|---|---|
| 103. Books, magazines, newspapers | 0.184 | (63) | 0.059 | (110) | 0.243 | (118) |
| 104. Other publishing industry products | 0.213 | (57) | 0.421 | (76) | 0.634 | (108) |
| 105. Misc. industrial products | 0.433 | (42) | 0.325 | (84) | 0.758 | (101) |
| 106. Electricity | 0.050 | (97) | 0.514 | (72) | 0.564 | (111) |
| 107. Water works, supply | 0.378 | (48) | 0.041 | (112) | 0.421 | (116) |
| 108. Construction | 0.945 | (11) | 0 | (120) | 0.945 | (81) |
| 109. Distribution, trucking | 0.078 | (89) | 0.885 | (55) | 0.963 | (76) |
| 110. Wholesale, retail trade | 0.064 | (93) | 0.366 | (83) | 0.429 | (115) |
| 111. Train transportation | 0.305 | (52) | 0.582 | (68) | 0.887 | (88) |
| 112. Boat transportation | 0.146 | (70) | 0.822 | (60) | 0.968 | (75) |
| 113. Air transportation | 0.489 | (39) | 0.241 | (92) | 0.730 | (104) |
| 114. Bus transportation | 0.794 | (19) | 0.826 | (59) | 1.620 | (19) |
| 115. Communications | 0.099 | (82) | 0.024 | (114) | 0.124 | (120) |
| 116. Restaurants, hotels | 0.689 | (26) | 0.088 | (107) | 0.777 | (100) |
| 117. Non-vehicle repairs | 0.062 | (95) | 0.459 | (74) | 0.522 | (113) |
| 118. Vehicle repairs | 0.208 | (59) | 0.790 | (62) | 0.998 | (73) |
| 119. Hospitals | 0.948 | (10) | 0.000 | (119) | 0.948 | (80) |
| 120. Misc. services | 0.064 | (92) | 0.093 | (105) | 0.157 | (119) |

less, we can compare the ranking of sectors by broad category (agriculture, light industry, etc.) to detect any differences or similarities in the results.

Locatelli's results, reported in Table V, are based on the Jones [12] method. In the Jones method, much like that of Rasmussen [15], backward linkages are computed by taking the column sum of the inverted Leontief matrix. Forward linkages in the Jones method are calculated by taking the row sums of the output inverse.[7] In the methods of both Jones and Rasmussen, a unitary final demand vector is implicitly assumed, as opposed to the use of the actual final demand vectors employed in the Cella method. In the Cella method, the percentage of a sector's output that is devoted to either final demand or intermediate demand has a bearing on the linkage estimates. In terms of equation (6), we can see that, ceteris paribus, the higher a sector's output that is devoted to final demand, the greater will be its backward linkage measure (and the smaller its forward linkage measure).

The way in which we normalize our linkages based on the Cella method (Table IV) also differs from that used in conventional methods such as that employed by

[7] The output inverse is calculated by (1) creating the output coefficient matrix, whose typical element is formed by taking the sales of sector $i$ to sector $j$ and dividing by total sales of sector $i$ and (2) taking the inverse of this matrix.

TABLE V

LOCATELLI'S LINKAGE ESTIMATES FOR 1970

| Sector | *BL* | Rank | *FL* | Rank |
|---|---|---|---|---|
| 1. Forestry and fishing | 1.078 | (86) | 2.149 | (19) |
| 2. Crop growing | 1.260 | (78) | 2.129 | (21) |
| 3. Livestock | 1.411 | (71) | 1.836 | (36) |
| 4. Misc. agriculture | 1.364 | (74) | 1.867 | (33) |
| 5. Mining | 1.358 | (78) | 2.100 | (22) |
| 6. Combustible mineral extraction | 0.078 | (87) | 3.168 | (4) |
| 7. Cement | 1.597 | (50) | 2.188 | (17) |
| 8. Glass | 1.414 | (69) | 1.971 | (26) |
| 9. Other nonmetallic mineral products | 1.491 | (64) | 2.140 | (20) |
| 10. Pig iron | 2.310 | (4) | 3.047 | (2) |
| 11. Sheet metal | 2.161 | (7) | 2.542 | (9) |
| 12. Cast iron, steel | 1.721 | (35) | 2.289 | (14) |
| 13. Nonferrous metals | 1.705 | (37) | 2.918 | (6) |
| 14. Miscellaneous metal products | 1.834 | (24) | 1.944 | (28) |
| 15. Pumps and engines | 1.688 | (40) | 1.398 | (52) |
| 16. Machine parts | 1.571 | (55) | 2.503 | (10) |
| 17. Ind. machines, equipment | 1.497 | (62) | 1.776 | (37) |
| 18. Agricultural machinery | 1.751 | (32) | 1.369 | (55) |
| 19. Office equipment | 1.694 | (39) | 1.068 | (71) |
| 20. Tractors | 1.936 | (18) | 1.484 | (47) |
| 21. Electric energy equipment | 1.563 | (56) | 1.446 | (49) |
| 22. Electric conductors | 1.445 | (66) | 1.940 | (30) |
| 23. Electric material, appliance repair | 1.590 | (52) | 1.691 | (40) |
| 24. Electrical appliances | 1.622 | (47) | 1.154 | (63) |
| 25. Electronic equipment | 1.411 | (70) | 2.291 | (13) |
| 26. Communications equipment | 1.753 | (31) | 1.201 | (60) |
| 27. Automobiles | 1.964 | (17) | 1.056 | (74) |
| 28. Buses, trucks | 2.207 | (6) | 1.062 | (73) |
| 29. Vehicle motors, parts | 1.681 | (41) | 1.875 | (32) |
| 30. Naval industry | 1.538 | (58) | 1.289 | (56) |
| 31. Train production, repair | 1.610 | (48) | 1.535 | (46) |
| 32. Lumber | 1.658 | (43) | 1.979 | (25) |
| 33. Furniture | 1.739 | (34) | 1.063 | (72) |
| 34. Pulp mills | 1.783 | (29) | 3.331 | (3) |
| 35. Paper | 1.603 | (49) | 2.283 | (15) |
| 36. Paper and cardboard | 1.822 | (26) | 2.253 | (16) |
| 37. Rubber | 1.592 | (51) | 1.983 | (24) |
| 38. Leather and hides | 1.395 | (73) | 1.569 | (45) |
| 39. Chemical elements | 1.639 | (46) | 2.988 | (5) |
| 40. Alcohol | 1.969 | (16) | 2.158 | (18) |
| 41. Petroleum refining | 1.357 | (76) | 2.051 | (23) |
| 42. Coal derivatives | 1.644 | (45) | 3.827 | (1) |
| 43. Chemical resins | 1.493 | (63) | 2.689 | (8) |
| 44. Vegetable oils | 1.828 | (25) | 1.846 | (34) |
| 45. Paints, tints, solvents | 1.572 | (54) | 2.485 | (11) |
| 46. Misc. chemical products | 1.488 | (65) | 2.347 | (12) |
| 47. Pharmaceuticals | 1.237 | (79) | 1.371 | (54) |
| 48. Cosmetics | 1.768 | (30) | 1.089 | (69) |
| 49. Plastics | 1.537 | (60) | 1.957 | (27) |

TABLE V (Continued)

| Sector | BL | Rank | FL | Rank |
|---|---|---|---|---|
| 50. Natural fiber mills | 1.929 | (19) | 1.840 | (35) |
| 51. Synthetic fiber mills | 1.798 | (27) | 1.645 | (42) |
| 52. Natural textile mills | 1.929 | (20) | 1.605 | (44) |
| 53. Other textiles | 1.650 | (44) | 1.482 | (48) |
| 54. Clothing | 1.996 | (14) | 1.033 | (77) |
| 55. Footwear | 1.696 | (38) | 1.005 | (85) |
| 56. Coffee processing | 2.042 | (10) | 1.941 | (29) |
| 57. Coffee mills, instant coffee | 3.805 | (1) | 1.081 | (70) |
| 58. Rice processing | 1.994 | (15) | 1.041 | (76) |
| 59. Flour mills | 1.662 | (42) | 1.621 | (43) |
| 60. Other vegetable products | 1.842 | (23) | 1.200 | (63) |
| 61. Meat products | 2.018 | (13) | 1.168 | (62) |
| 62. Poultry products | 2.067 | (8) | 1.110 | (67) |
| 63. Fish products | 1.861 | (22) | 1.119 | (66) |
| 64. Dairy products | 2.045 | (9) | 1.143 | (64) |
| 65. Sugar mills | 1.883 | (21) | 1.426 | (50) |
| 66. Sugar refining | 2.303 | (5) | 1.055 | (75) |
| 67. Bakery products | 2.034 | (12) | 1.027 | (79) |
| 68. Vegetable oil, fat refining | 2.598 | (2) | 1.278 | (57) |
| 69. Other food products | 1.787 | (28) | 1.653 | (41) |
| 70. Beverages | 1.579 | (53) | 1.135 | (65) |
| 71. Tobacco | 1.554 | (57) | 1.030 | (78) |
| 72. Books, magazines, newspapers | 1.424 | (68) | 1.243 | (58) |
| 73. Misc. industrial products | 1.538 | (59) | 1.237 | (59) |
| 74. Electricity | 1.099 | (84) | 1.890 | (31) |
| 75. Water works, supply | 1.408 | (72) | 1.010 | (83) |
| 76. Construction | 1.745 | (33) | 1.023 | (81) |
| 77. Distribution, trucking | 1.135 | (81) | 1.411 | (51) |
| 78. Train transportation | 2.041 | (11) | 1.699 | (39) |
| 79. Boat transportation | 1.219 | (80) | 1.389 | (53) |
| 80. Other transportation | 1.444 | (67) | 1.011 | (82) |
| 81. Communications | 1.090 | (85) | 1.025 | (80) |
| 82. Finance | 1.102 | (82) | 1.000 | (86) |
| 83. Restaurants, hotels | 1.710 | (36) | 1.008 | (84) |
| 84. Equipment repair | 1.306 | (77) | 1.728 | (38) |
| 85. Hospitals | 1.515 | (61) | 1.000 | (87) |
| 86. Other services | 1.101 | (83) | 1.098 | (68) |
| 87. Repair pieces | 2.384 | (3) | 2.869 | (7) |

Source: [14, pp. 107–12].

Jones. While we normalize by dividing linkage estimates by sectoral output, the Jones method "normalizes" the results by assuming the same unit increase in final demand for each sector.

In light of the methodological differences between the Jones and Cella methods, it is not surprising that Locatelli's results (Table V) are somewhat different from our normalized results in Table IV. Some of the particular sectors that Locatelli indicates have high forward linkages per unit of output—such as coal derivatives (sector 42 in Table V), pulp mills (sector 34), and mineral combustibles (sector 6), are notably absent from our list of the top twenty sectors by *FLVP* (Table IV). Some sectors that we indicate have high backward linkages per unit, such as construction, are also not ranked highly by Locatelli. Nevertheless, some important similarities emerge between our estimates and those of Locatelli. Both sets of estimates show that transportation equipment (automobiles, trucks and buses), as well as food products, are the sectors of the economy that have the greatest backward linkages per unit of output. Similarly, sectors within the metallurgy industry rank highly in terms of forward linkages per unit of production. Both methods show that many service sectors have low forward linkages, such as communications, hospitals, and restaurants and hotels. Thus, in spite of the differences in the Jones and Cella methods, some important similarities emerge through our comparison of results based on each alternative methodology.

A principal advantage of the Cella method for calculating linkages is that it allows for a mathematically consistent aggregation of backward and forward linkages into total linkages. As Cella [7] notes, in the Jones method, employed by Locatelli, we cannot consistently aggregate the backward and forward linkage measures to derive a comprehensive measure of total linkages. This explains why Locatelli [14] does not report total linkages in his study. Our ability to derive a consistent measure of total linkages is of great relevance to the debate on linkages and economic development in Brazil. Of principal concern in this debate is whether or not the Brazilian state has especially supported the most linkage-intensive sectors; in order to assess which sectors are most linkage-intensive, the most appropriate measure is total linkages per unit of output. Previous studies on the linkage intensity of Brazilian development [2] [6] [11] [13] [14] have been hampered by their inability to comprehensively estimate total linkages. The linkage intensity of Brazil's development model is addressed in Section V, where we assess the relationship between total linkages and variables measuring the sectoral priorities of Brazilian policymakers.

## IV. LINKAGES AND OTHER CRITERIA OF SECTORAL PERFORMANCE

Spearman correlation coefficients between linkage measures and other variables assessing sectoral performance are presented in Table VI. Regarding the non-normalized linkage measures, the figures indicate a weak relationship between labor intensity and backward linkages. This does not imply that high *BL* sectors have favorable employment or distributive consequences, however, as no significant correlations emerge between *BL, GINI,* or *EMPLOY*. As one would expect, Table VI reflects the fact that larger sectors will tend to have higher linkages, as *BL, FL,* and *TL* are all significantly correlated with *VALPROD*.

Turning to our normalized linkage measures, the results indicate that a development strategy that gives a high priority to those sectors with high backward linkages per unit of output will have a favorable impact on employment. A high level of *BLVP* is also associated with a relatively low level of intermediate import use,

TABLE VI

CORRELATIONS AMONG LINKAGE AND SECTORAL PERFORMANCE INDICATORS

| | *BL* | *FL* | *TL* | *BLVP* | *FLVP* | *TLVP* |
|---|---|---|---|---|---|---|
| *EMPLOY* | 0.093 | −0.036 | 0.054 | 0.205* | −0.179* | −0.067 |
| *GINI* | −0.088 | −0.130 | −0.146 | −0.131 | 0.116 | 0.039 |
| *WPOOR* | 0.033 | −0.004 | 0.024 | 0.240* | −0.140 | 0.020 |
| *K/L* | −0.151** | 0.080 | −0.076 | 0.180* | 0.067 | −0.064 |
| *VALPROD* | 0.609* | 0.458* | 0.759* | −0.007 | −0.192* | −0.247* |
| *IMPORT* | −0.052 | 0.132 | 0.035 | −0.159** | 0.263* | 0.207* |
| *DRC80* | 0.076 | −0.089 | −0.044 | 0.107 | −0.050 | 0.036 |

Notes: 1. Figures indicate Spearman correlation coefficients.
2. The methodology used to derive all the variables except *DRC80* is similar to that described in [8]. *DRC80* data (only available for industry and agriculture) are taken from [9].
3. Legend: *EMPLOY*=total employment (in man-years) generated per million cruzeiro increase in final demand, *GINI*=Gini coefficient of income distribution, which indicates distribution of the marginal income resulting from a unit increase in final demand for sectoral output, *WPOOR*=share of wage income accruing to the poor per unit increase in sectoral final demand, *K/L*=capital income / labor income ratio (from income derived from a unit increase in sectoral final demand), *VALPROD*=value of production in sector, *IMPORT*=intermediate imports required per unit increase in final demand, *DRC80*=domestic resource cost for 1980.

* Significant at the 0.05 confidence level.

** Significant at the 0.10 confidence level.

given the negative relationship between *BLVP* and *IMPORT*. These results are not surprising, given that many of the sectors with high backward linkages per unit of output are traditional, labor-intensive activities (Table IV). High forward linkages per unit of output, however, are associated with low employment creation and relatively heavy reliance on imported inputs. Likewise, high total linkages per unit of output are positively correlated with import use. There are no negative employment or distributive repercussions in promoting sectors characterized by high *TLVP*, however, as no significant correlation emerges between *TLVP*, *EMPLOY*, or *GINI*. It should also be noted that a sector's ability to generate linkages (per unit of output) does not increase with sector size; in fact, both forward and total linkages per unit output are negatively correlated with the value of sectoral production.

None of the linkage measures show any systematic relationship with our efficiency measure, domestic resource cost (*DRC*). Domestic resource cost measures, at shadow prices, the total cost of domestic resources needed to generate a dollar of foreign exchange. The lower a sector's *DRC*, the greater the amount of foreign exchange that can be earned with a given amount of resources. Given the absence of any significant relationship between a sector's *DRC* and its ability to create linkages with other economic activities, our results do not indicate that a linkage-intensive development strategy will improve aggregate economic efficiency.

TABLE VII

SPEARMAN RANK CORRELATIONS AMONG LINKAGE MEASURES AND INDICATORS OF SECTORAL PROTECTION AND PROMOTION

| | *BL* | *FL* | *TL* | *BLVP* | *FLVP* | *TLVP* |
|---|---|---|---|---|---|---|
| *NET* | −0.242** | 0.051 | −0.152 | −0.204 | 0.054 | −0.290* |
| *EXSUB* | −0.181 | 0.063 | 0.098 | −0.221 | 0.039 | −0.249** |
| *STATESHR* | −0.121 | 0.075 | −0.153 | −0.224** | 0.082 | −0.157 |
| *STATEINV* | −0.096 | 0.093 | 0.121 | −0.212 | 0.076 | −0.160 |
| *MNCSHR* | 0.100 | 0.030 | 0.092 | 0.008 | 0.153 | −0.193 |
| *MNCINV* | 0.332* | 0.213 | 0.445* | 0.060 | −0.127 | −0.085 |

Notes: 1. Correlations computed for industrial sectors. See Appendix for description of variables.

2. Legend: *NET*=net effective protection, 1981, *EXSUB*=nominal export subsidy rate by sector, *STATESHR*=share of state enterprises in total sectoral production, *STATEINV*=share of state enterprises in that sector, *MNCSHR*=share of multinational corporations in total sectoral production, *MNCINV*=value of multinational corporation production in that sector.

* Significant at the 0.05 confidence level.

** Significant at the 0.10 confidence level.

## V. LINKAGES AND THE BRAZILIAN MODEL OF ECONOMIC DEVELOPMENT

Has the Brazilian model of development given special emphasis to linkage-intensive sectors? To examine this proposition, correlations between variables that assess sectoral priorities of policymakers and linkage measures were calculated.[8] Examining the structure of protection, it appears that high linkage sectors are not given special priority; in fact, sectors with high total linkages per unit of output tend to receive the least protection from imports. This can be seen in Table VII from the statistically significant correlations between total linkages per unit of output (*TLVP*) and our measure of protection, net effective protection (*NEP*). High linkage sectors do not receive special attention in Brazil's export promotion program; in fact, sectors with high linkages per unit of output tend to receive a relatively small amount of export subsidies. The only way in which state policy has contributed to a linkage-intensive strategy is through the operation of state enterprises. State enterprises tend to be found in sectors with high levels of forward linkages and forward linkages per unit of output, such as metallurgy and chemicals. The lack of any statistically significant relationship between our linkage per-unit output measures and the state share of investment is a bit misleading, as state enterprises are concentrated in a few select sectors. Hence, while state

[8] The methodology employed in this section (correlating policy variables with linkage measures) follows that Locatelli [13] [14]. Only industrial sectors for which compatible data could be found (in terms of definitions for sectors) were used for the correlations.

enterprises are absent in some high linkage sectors, those sectors in which state enterprises are found tend to have relatively high forward linkages.

The Brazilian model of economic development has relied heavily on multinational corporations (MNCs) to industrialize the economy. Of interest, then, is an assessment of whether or not this reliance on multinationals has been consistent with a linkage-intensive development strategy. Table VII reveals that transnational corporations have chosen to locate in high linkage sectors of the economy. MNC operations tend to be found in sectors with high backward and total linkages, as witnessed by the significant correlation between *MNCINV*, *BL*, and *TL*. Multinational investment is not necessarily skewed towards sectors with the greatest linkages per unit of output, however, as no correlation emerges between *MNCINV* and *TLVP*. Thus, a mixed picture emerges when evaluating the role of multinationals in Brazil: while they have invested in many important linkage-intensive sectors (such as automobiles and chemicals), some linkage-intensive sectors have been ignored.

## VI. SUMMARY

This paper has provided mathematically consistent calculations of the forward, backward, and total linkages in the Brazilian economy in 1975. Previous applications of the linkages concept to less developed countries, including Brazil, have used measures that either do not allow a disaggregation of total linkages into a forward and backward component, or are based on a mathematically inconsistent disaggregation.

Our results for the Brazilian economy reveal that high linkages cannot be exclusively associated with modern industrial sectors. This is especially true with respect to backward linkages, as many sectors with a high level of *BL* and *BL* per unit of output are found outside of heavy industry. These results are consistent with those of Locatelli [13] [14] for 1970, who, using the Jones method of computing linkages, found that consumer nondurable goods sectors are among the "key" sectors of the Brazilian economy. Our calculations also reveal, however, that there are some important differences between key sectors from the standpoint of backward and forward linkages. Sectors that generate a relatively high level of *BL* per unit of output tend to perform more favorably on criteria such as reliance on domestic suppliers (low import dependence) and employment generation. Activities with high *FL* per unit of output, on the other hand, tend to perform poorly on these grounds; similarly, high total linkages per unit of output are associated with a reliance on imported inputs. None of our linkage measures have any consistent relationship with domestic resource cost, our measure of efficiency. Hence, while a development strategy that promotes key sectors from a backward linkage standpoint may have a favorable impact on employment generation, there is no reason to suppose that this will lead to a more efficient allocation of resources.

Our results cast doubt on the proposition that the Brazilian model of economic development has been linkage-intensive. In fact, many aspects of economic policy, such as trade policy, tend to retard the growth of linkage-intensive sectors. State investment tends to be located in sectors with high total linkages, such as metallurgy and chemicals; nevertheless, the state is absent in other high linkage activities. Hence, while Brazilian economic policy may have helped foment a vertically integrated industrial economy, the success of this endeavor cannot be attributed to conscious government effort to promote linkage-intensive economic activities.

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# APPENDIX

## VARIABLES USED IN TABLE VII

Data for sectoral performance by sector was drawn from a number of sources. Industrial sectors for which compatible data could not be found were not included in the correlations.

*NET* = net effective protection, as calculated in Tyler [17].

*EXSUB* = export subsidies as a percentage of the value of export sales, as calculated in Tyler [17].

*STATESHR* = share of state enterprises in sectoral sales. The shares for each manufacturing sector were calculated with 1980 and 1981 data from Willmore [18] and Baer [3].

*STATEINV* = state enterprise output, 1975; calculated by multiplying 1975 sectoral production by the state enterprise share of sales.

*MNCSHR* = multinational corporation share of sectoral sales, as given by the same data sources used for *STATESHR*.

*MNCINV* = multinational corporation output, 1975; calculated by multiplying 1975 sectoral production by the multinational corporation share of sales.